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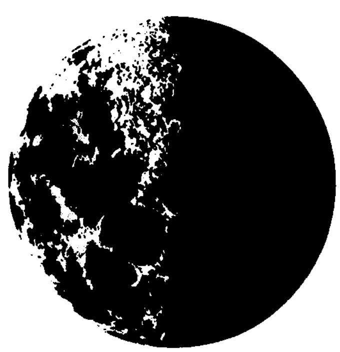

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GENERAL ~~TEST PLAN~~
RESEARCH AND DEVELOPMENT FOR
PROJECT APOLLO SPACECRAFT (U)

NAS9-150

Volume II. Individual System Tests

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TABLES

INTRODUCTION

Volume II presents detailed test plans for the individual system tests described in Section 2.0 of Volume I. These detailed test plans define the manner in which the approved subcontractor and S&ID will accomplish the testing required to qualify the subassemblies and individual systems for inclusion in the Apollo spacecraft.

Included in each test plan will be information regarding the equipment and configuration of the test article; test concepts and objectives; test locations; data requirements, receiving, acceptance, and checkout tests; significant test procedures; and other essential information.

In general, tests on components of subcontractor-furnished systems will not be performed by S&ID.

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1.0 SERVICE PROPULSION SYSTEM

1.1 SCOPE

This section consists of the development test program for the service propulsion system. It is divided into two main sections: (1) the subcontractor (Aerojet General) test program and (2) S&ID's development test program. The section is limited to engineering development, evaluation, and design verification tests. Qualification tests are covered in SID 62-109-3.

The subcontractor's development test program consists of a preliminary development test program, a simulated high altitude test program, and a development evaluation test program. The S&ID development test program consists of two phases of tests at the breadboard level to determine subsystems compatibility, verification of component supplier's test results and evaluation of the system prior to the integrated systems test.

1.2 SUBCONTRACTOR TEST PLAN (AEROJET-GENERAL)

1.2.1 Thrust Chamber and Injector Preliminary Development Test Plan (Phase I)

1.2.1.1 Objective

The objective of this test plan is to develop, optimize, and verify performance and configuration of a rocket engine complying to the requirements of S&ID Procurement Specification M901-0009.

1.2.1.2 Test Plan

1.2.1.2.1 Injector Pattern. To determine the injector configuration and performance characteristics, injectors have been designed to various configurations and tested to develop the optimum configuration. Testing will be accomplished with work horse chambers, which will contribute to ultimate chamber geometry definition. Approximately 124 tests will be performed, using 18 experimental injectors, 3 steel test chambers, and 4 steel chamber sections. Tests will include induced instability, fuel and oxidizer ratio investigation, and altitude starts.

1.2.1.2.2 Stabilized Operation. Tests will be conducted to optimize the injector orifice length over diameter ratio, investigate combustion stability, evaluate injector face cooling, and obtain preliminary heat transfer data. Mixture ratio variations will be investigated for off-design engine operation. Approximately 76 tests will be performed using 2 experimental injectors, 13 test chambers, and experimental propellant valves.

1.2.1.2.3 Chamber Material. Tests will be conducted on chambers of alternate materials and bonding agents for comparison with chambers of phenolic-refrasil construction. These tests will determine the optimum materials currently available for thrust chamber usage. This series of tests is to be conducted in three phases as follows:

1. Preliminary evaluation. Testing of material specimens with laboratory type equipment.

2. Subscale tests. Subscale chambers of various ablative materials will be fired at both sea-level and altitude conditions. Approximately 90 tests are to be performed on approximately 18 chambers at sea level conditions, and 6 subscale chambers are to be expended with a total of 102 firings at altitude (AEDC). Nozzle extensions will be evaluated during the AEDC tests.

3. Full-scale tests. 12 full-scale tests utilizing 4 chambers will be conducted for final evaluation.

1.2.1.2.4 Compatibility. Approximately 50 tests will be conducted, utilizing 11 chambers for the following purposes:

1. To verify injector/chamber compatibility
2. To evaluate flange
3. To demonstrate restart capability
4. To finalize wall thickness
5. To demonstrate performance at high and low temperature
6. To demonstrate performance with abnormal start pressures
7. To investigate effects of plugged injector
8. To demonstrate performance with abnormally high chamber pressure (P_c)

9. To verify prototype flight weight chamber performance and capabilities under conditions of high and low mixture ratio, high and low temperature, abnormal starting pressure, above normal P_c, and abort mission firing duration

To evaluate gimbal actuator performance characteristics and durability while subjected to varying environmental conditions, several actuators will be operated while they are subjected to shock, high and low temperature, vibration, etc.

1.2.1.2.5 Nozzle Extension. Tests will be conducted to provide preliminary evaluation of the nozzle extension configuration, material selection, and chamber nozzle attach flange location and configuration. Tests will be conducted on various nozzle and joint configurations using nonaugmented straight pipe diffusers.

1.2.1.2.6 Engine Mounts. The test program is designed to evaluate the structural integrity of the engine mounts, to verify load carrying capabilities, and to determine failure loads. This test program will include component tests, cyclic and shock-loading tests, and a rotational resonant frequency test of the complete mount.

1.2.1.2.7 Propellant Lines. Tests will be conducted to develop and verify propellant line configuration.

1.2.1.3 Equipment

Aerojet test facilities will be equipped with thrust measuring stands, tankage, pressurization systems, altitude chambers, environmental simulation equipment, and high-response recording and measuring instruments. ARO, Incorporated (Tullahoma) equipment will be used for AEDC tests.

1.2.1.4 Facilities

The development tests of the service propulsion engine system (see Table 1-1) will be conducted at Azusa and Sacramento, California, and at the AEDC facility at Tullahoma, Tennessee.

Table 1-1. Service Propulsion Engine System Development Tests

Tests	Facility	Location
Injector pattern	Building 23A	Azusa
Stabilized operation	Building 23C	Azusa
Chamber material	Building 23C T-4	Azusa (AEDC) Tullahoma
Compatibility	Building 23C Building 23A H-1 C-10	Azusa Azusa Sacramento Sacramento
Nozzle extension	H-3	Sacramento
Engine mounts	Building 135 Building 42	Azusa Azusa
Propellant lines	Building 42	Azusa

1.2.2 <u>Thrust Chamber Valve Preliminary Development Test Plan</u>

1.2.2.1 Objective

Development tests will be performed on thrust chamber valve clusters prior to qualification and/or production to fully analyze the component function and ability to withstand environments. Development tests consist of functional and environmental tests considered critical to valve operation.

1.2.2.2 Test Plan

1.2.2.2.1 <u>Functional</u>. Tests will be performed to allow functional evaluation of the thrust chamber valves on a component level. Transient flow characteristics, burst pressure tests, actuation rates, proof pressure, and leak evaluation tests will be conducted. Two experimental and four pre-prototype valves will be used in the tests.

1.2.2.2.2 <u>Environmental</u>. Several valve assemblies will be operated while being subjected to high and low temperatures, high and low voltage, and vibration and acoustic environments. Life duty cycling also will be accomplished.

1.2.2.3 Equipment

All necessary equipment will be provided by AGC.

1.2.2.4 Facilities

Thrust chamber valve functional and environmental development tests will be performed in Building 135 at Azusa, California.

1.2.3 <u>Gimbal Actuator Preliminary Development Test Plan</u>

1.2.3.1 Objective

Development testing of the gimbal actuation system will be conducted in two phases. The first phase will consist of testing performed at the actuator level to establish functional and structural integrity of the actuator as a component.

The second phase of the testing will be conducted on gimbal actuator systems that will include the engine loads, structural compliance, damping and compensation networks, and the servo amplifier as well as the actuator. The purpose of these tests will be to develop a thrust vector control system that meets the response characteristics demanded by the vehicle guidance system and is compatible with the engine and supporting structure dynamics.

The service module structure is sufficiently complex to make it virtually impossible to simulate. The characteristics of this structure will dominate the selection of gains, damping factors, and compensation devices. For these reasons, development testing on a "hard" test stand will not be useful in establishing final stability and response characteristics. That can only be accomplished in an actual flight-weight service module structure or with a good computer simulation. These tests can be useful, however, in establishing actuator and gimbal characteristics for use in computer studies as well as for environmental testing.

1.2.3.2 Test Plan

1.2.3.2.1 <u>Functional (Phase I)</u>. Tests will be performed to:

1. Establish hysteresis, dead band, and linearity for low-amplitude control signal inputs.

2. Establish response capabilities and step and sinusoidal inputs at varying amplitudes and frequencies. Tests to establish power

demands under various conditions of load with step, ramp, and sinusoidal inputs at varying amplitudes and frequencies are not expected to be made.

3. Determine structural integrity and stiffness of actuator assembly

4. Establish operating life and durability under simulated operational environments including extended exposure to high vacuum.

5. Evaluate dielectric strength and insulation resistance of all electrical components.

1.2.3.2.2 Functional (Phase II). Tests will be performed to:

1. Establish response characteristics with simulated inertial, spring and friction loads, with simulated structural compliances and with varying damping factors. These tests are to tentatively establish the limiting gains and damping required in the minor loop to provide satisfactory control and response to low-amplitude, low-frequency inputs as well as satisfactory response and stability for larger-amplitude, high-frequency inputs.

2. Develop parametric data by utilizing identically programmed inputs for cold-gimbaling, multiple-restart, simulated flight-duty-cycle tests.

3. Verify structural and dynamic compatibility using the same taped program input utilized in 2 with flight-weight structure and engine assemblies.

4. Determine effects of engine operational environments on the actuator control capabilities. Cold and hot gimbaling tests will be made on engines being fired. Inputs identical to those in 2 and 3 will be used.

1.2.3.2.3 Environmental. Tests will be conducted on the development actuators to tentatively establish the capability to function satisfactorily during and after exposure to the environments of shock, vibration, acceleration, and temperature extremes. Units will be operated before, during, and after each test to establish the effects of each environment.

1.2.3.3 Equipment

All equipment for gimbal actuator tests is to be supplied by AGC. It should be noted that AGC has chosen circuitry for their servo amplifier different from Minneapolis-Honeywell (whose amplifier is not available for these tests).

1.2.3.4 Facilities

Gimbal actuator tests will be conducted in Building 135 at Azusa, California, and "C" area at Sacramento, California.

1.2.4 Simulated High-Altitude Tests (Phase II - Design Evaluation)

1.2.4.1 Objective

The objective of this program is to evaluate the following operating characteristics of the S/P engine at altitudes above 110,000 feet:

1. Performance of the nozzle extension
2. Engine operation at abnormal levels of P_c and mixture ratio (O/F)
3. Engine operation when supplied with propellants from only one bank of valves
4. Effect of gimbaling the engine
5. Ablation characteristics, char depth, and life capability of the ablative chamber
6. The surface temperature profile of ablative chamber and nozzle extension
7. The effects of heat "soak-back" on injector and valves during coast periods
8. Start and shutdown impulse characteristics
9. Thrust coefficient (Cf) and specific impulse (Isp)

1.2.4.2 Test Plan

Table 1-2 outlines the tests to be performed at AEDC during the simulated high-altitude design evaluation tests. Three engines will be expended.

1.2.4.3 Equipment

All equipment for this series of tests is to be furnished by AGC or ARO.

1.2.4.4 Facilities

This series of tests is to be conducted in existing AEDC facilities at [redacted]llaho[redacted], Tennessee.

Table 1-2. AEDC High-Altitude Design Evaluation Tests

Test Number	Number of Firings	Firing-Duration (sec)	Hardware or Conditions	Remarks
1	1	10	Checkout firing	
Engine No. 1	1	40	High manufacturing tolerance nozzle	Thrust vector measurement with 60:1 nozzle on all tests
	1	50	Low manufacturing tolerance nozzle	
	1	50	Low manufacturing tolerance nozzle, Single-valve (A) operated	
	1	50	Single-valve (A) operated	
	1	50	High manufacturing tolerance nozzle Alternate-valve (B) operated,	
	1	50	High-manufacturing tolerance nozzle Single valve (B) operated	
	1	300	Low manufacturing tolerance nozzle Double-valve operation	
	1	120	Nozzle pierced prior to test	

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Table 1-2. AEDC High-Altitude Design Evaluation Tests (Cont)

Test Number	Number of Firings	Firing-Duration (sec)	Hardware or Conditions	Remarks
2	1	60	Simulated preflight firing	Thrust vector measurement with 60:1 nozzle
Engine No. 2	1	17	1st firing of mission profile, Coast 30 minutes	
	1	7	Coast 30 minutes	
	1	7	Coast 30 minutes	
	1	400	Coast 12 hours	
	19	5	Coast 1 minute	
	1	5	Coast 1 hour	
	1	110	Coast 8 hours	
	1	5	Coast 30 minutes	
	1	2	Coast 30 minutes	
	1	12	Coast 30 minutes	Thrust vector measurement with 60:1 nozzle
3	1	30	Acceptance test	Thrust vector measurement without nozzle
(New chamber	1	60	Simulated preflight firing	Thrust vector measurement with 60:1 nozzle
on	1	18	30-minute coast	Simulated abort mission
engine	1	635	8-hour coast	Gimbal test
No. 1)	1	2	30-minute coast	Gimbal test
	1	5	30-minute coast	Thrust vector measurement with 60:1 nozzle

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Table 1-2. AEDC High-Altitude Design Evaluation Tests (Cont)

Test Number	Number of Firings	Firing-Duration (sec)	Hardware or Conditions	Remarks
4	1	60	Simulated preflight firing	Thrust vector measurement with 60:1 nozzle
Engine No. 3	1	18	Coast 30 minutes	
	1	Continuous firing until 43,500 lb of propellant are consumed	High P_c, Coast 8 hours	
	1	2	High P_c, coast 30 minutes	
	1	5	High P_c, coast 30 minutes	Thrust vector measurement with 60:1 nozzle
5	1	30	Acceptance test	Thrust vector measurement with 60:1 nozzle
(New chamber on engine No. 2)	1	60	Simulated preflight firing	
	1	17	1st firing of mission profile, Coast 30 minutes	
	1	7	Coast 30 minutes	
	1	7	Coast 30 minutes	
	1	100	Coast 4 hours, high M. R.	
	1	300	Coast 8 hours, high M. R.	
	1	100	Coast 4 hours, high M. R.	

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Table 1-2. AEDC High-Altitude Design Evaluation Tests (Cont)

Test Number	Number of Firings	Firing-Duration (sec)	Hardware or Conditions	Remarks
5 (Cont)	1	50	Coast 1 hour, high M. R.	
	1	5	Coast 30 minutes, high M. R.	
	1	5	Coast 30 minutes, high M. R.	Thrust vector measurement with 60:1 nozzle
6	1	30.0	Acceptance test	Thrust vector measurement without nozzle
(New chamber on engine No. 3)	1	60.0	Preflight firing	Thrust vector measurement with 60:1 nozzle
	5	0.400	30-second coast between firings	
	5	0.500		
	5	0.600		
	5	0.800		
	5	1.0		
	5	2.0		
	5	4.0		
	5	5.0		
	5	60.0		Gimbal test
	1	290.0	Low chamber pressure	Thrust vector measurement with 60:1 nozzle

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Table 1-2. AEDC High-Altitude Design Evaluation Tests (Cont)

Test Number	Number of Firings	Firing-Duration (sec)	Hardware or Conditions	Remarks
7	1	30	Acceptance test	Thrust vector measurement without nozzle
(New chamber on engine No. 2)	1	60	Simulate preflight firing	Thrust vector measurement with 60:1 nozzle
	1	17	30-minute coast	Mission profile
	1	7	30-minute coast	Gimbal test
	1	7	30-minute coast	Gimbal test
	1	400	12-hour coast	Gimbal test
	19	5	1-minute coast	Gimbal test
	1	5	1-hour coast	Gimbal test
	1	110	8-hour coast	Gimbal test
	1	5	30-minute coast	Gimbal test
	1	2	30-minute coast	Gimbal test
	1	12	30-minute coast	Thrust vector measurement with 60:1 nozzle

Note: Engines No. 1, 2, and 3 will be subjected to a 30-sec duration checkout firing at Azusa prior to testing at AEDC.

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1.2.5 Service Propulsion Prequalification Tests (Phase III)

1.2.5.1 Objective

The objectives of this program are as follows:

1. To demonstrate chamber duration, ability to perform mission duty cycles and intermittant restarts
2. Duration testing of thrust chamber valves at nominal and environmental conditions
3. Duration testing of gimbal actuators under simulated load and environmental conditions

1.2.5.2 Test Plan

1.2.5.2.1 Thrust Chamber Tests. These tests will be conducted to accomplish the following:

1. Incremental design duration. Six chambers will be expended. Each chamber will be fired in 200-second increments until failure occurs.
2. Integral design duration. Ten chambers will be expended. Each chamber will be fired for 500 seconds, 250 seconds, and a final firing to failure.
3. Mission profile. Eight chambers will be expended by firing in a manner representing a simulated mission profile.
4. Restarts. Two chambers will be subjected to short-duration restarts (125 each) until failure occurs.

1.2.5.2.2 Thrust Chamber Valve. Five valve assemblies will be subjected to life and environmental testing.

1.2.5.2.3 Gimbal Actuators. Ten gimbal actuators will be subjected to life and environmental testing.

1.2.5.3 Equipment

Chamber tests (1.2.5.2.1) will require the NAA-S&ID F-1 test fixture. All other equipment will be supplied by AGC.

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1.2.5.4 Facilities

Chamber tests (1.2.5.2.1) will be conducted in the C-11 stand at Sacramento. Valve and actuator tests (1.2.5.2.2 and 1.2.5.2.3) are to be accomplished in Building 135 at Azusa.

A.G.C. will provide all equipment for thrust chamber valve and gimbal actuator tests (1.2.5.2.2 and 1.2.5.2.3).

1.2.6 Test Schedule

The subcontractor test schedule is shown in Figure 1-1.

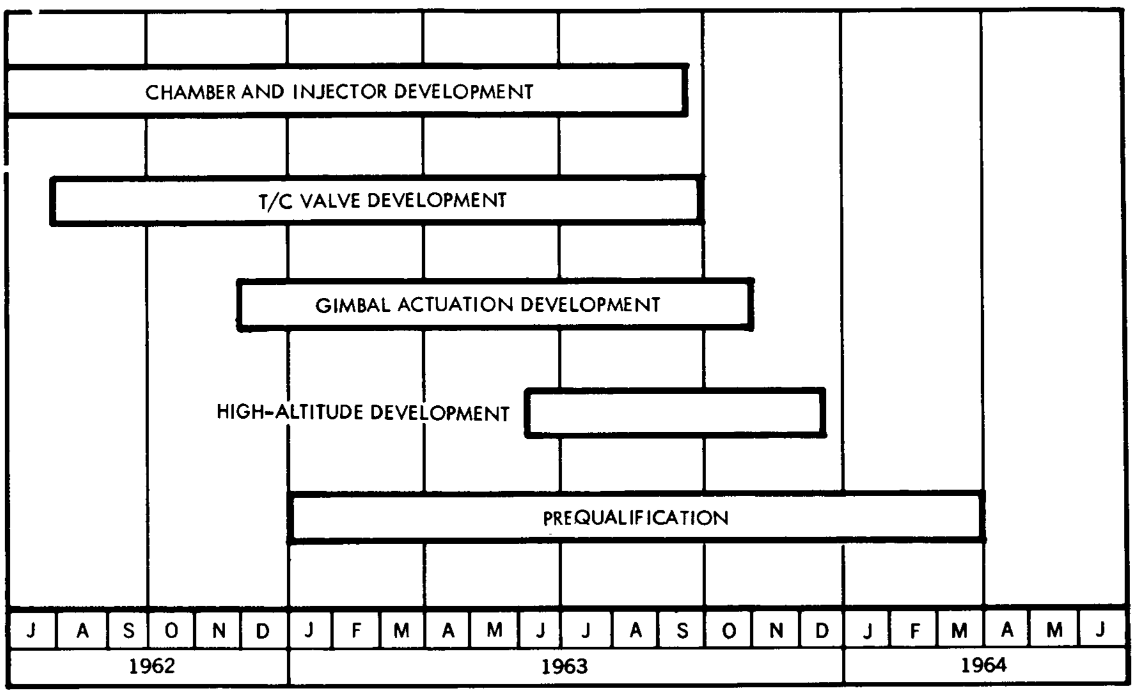

Figure 1-1. Service Module Propulsion Subcontractor Test Schedule

1.3 S&ID TEST PLAN

1.3.1 SPS Propellant System Test Plan

The development of the SPS propellant system will be accomplished by utilizing three test fixtures. These test fixtures are designated F-1, F-2, and F-3. The F-1 will be utilized to provide propellant system operational data that will be obtained during the Aerojet rocket engine tests.

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The F-3 will be utilized to provide preliminary evaluation of the propellant system through the use of cold flow tests. The F-2 (see Section 4.0 of Volume V) will be the primary propellant system development tool. All problems encountered during F-1 tests, F-3 tests, and AFRM 001 tests will be investigated and corrected on the F-2 fixture. A test plan involving the use of the F-1 and F-3 fixtures is detailed below.

1.3.1.1 F-1 Test Plan

The F-1 test fixture will consist of a structural steel framework to which are attached stainless steel fuel and oxidizer tanks, stainless steel helium bottles, and off-the-shelf propellant system components. The primary purpose of the F-1 test fixture is to provide a simulated propellant feed system to ensure that rocket engine performance will be compatible with spacecraft propellant feed system dynamics. The test fixture will be used during the rocket engine development evaluation program (paragraph 1.2.5) and will also be utilized in the rocket engine qualification and acceptance test programs as outlined in Volumes III and IV.

A secondary purpose of the test fixture is to provide propellant system operational data. This data will be obtained during the Aerojet engine tests.

1.3.1.1.1 Objectives. The use of the F-1 test fixture in conjunction with Aerojet rocket engine tests will support the development of the propellant system. The test program will provide evaluation of individual components, evaluation of subsystems and their interactions, and data to prove design concepts.

1.3.1.1.2 Test Plan. The test plan will consist entirely of rocket engine tests performed by Aerojet at its Sacramento facility. During the engine test programs, however, the following list of propellant system data will be monitored and recorded:

1. Pressure of helium in helium tank
2. Temperature of helium in helium tank
3. Solenoid valve No. 1 position
4. Regulator No. 1 inlet pressure
5. Regulator No. 1 inlet temperature
6. Regulator No. 1 outlet pressure
7. Regulator No. 1 outlet temperature

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8. Solenoid valve No. 2 position
9. Regulator No. 2 inlet pressure
10. Regulator No. 2 inlet temperature
11. Regulator No. 2 outlet pressure
12. Regulator No. 2 outlet temperature
13. Check valve No. 1 outlet pressure
14. Check valve No. 2 outlet pressure
15. Oxidizer tank No. 1 inlet pressure
16. Oxidizer tank No. 1, temperature No. 1
17. Oxidizer tank No. 1, temperature No. 2
18. Oxidizer tank No. 1, temperature No. 3
19. Oxidizer tank No. 1, temperature No. 4
20. Oxidizer tanks connecting-line pressure
21. Oxidizer tank No. 2 inlet pressure
22. Oxidizer tank No. 2, temperature No. 1
23. Oxidizer tank No. 2, temperature No. 2
24. Oxidizer tank No. 2, temperature No. 3
25. Oxidizer tank No. 2, temperature No. 4
26. Fuel tank No. 1 inlet pressure
27. Fuel tank No. 1, temperature No. 1
28. Fuel tank No. 1, temperature No. 2
29. Fuel tank No. 1, temperature No. 3
30. Fuel tank No. 1, temperature No. 4

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31. Fuel tanks connecting-line pressure
32. Fuel tank No. 2 inlet pressure
33. Fuel tank No. 2, temperature No. 1
34. Fuel tank No. 2, temperature No. 2
35. Fuel tank No. 2, temperature No. 3
36. Fuel tank No. 2, temperature No. 4
37. Fuel tank No. 2 flow valve actuation pressure
38. Oxidizer tank No. 2 flow valve actuation pressure
39. Oxidizer flowmeter inlet pressure
40. Oxidizer flowmeter inlet temperature
41. Oxidizer flowmeter outlet pressure
42. Oxidizer flowmeter outlet temperature
43. Oxidizer flow rate
44. Fuel flowmeter inlet pressure
45. Fuel flowmeter inlet temperature
46. Fuel flowmeter outlet pressure
47. Fuel flowmeter outlet temperature
48. Fuel flow rate

1.3.1.1.3 Equipment Requirements. The equipment required to accomplish the objectives of the test program will include the F-1 test fixture; pressure, temperature, and flow-sensing elements; indicating and recording equipment; and miscellaneous support equipment.

The F-1, as previously described, will consist of a structural steel framework to which are attached ASME coded gas and propellant tanks and the numerous components which make up the pressurization and propellant distribution subsystems. The F-1 fixture will be designed and fabricated by S&ID. After checkout at S&ID, the fixture will be shipped to the Sacramento facility of Aerojet General Corporation.

The pressure, temperature, and flow-sensing elements and indicating and recording equipment will be furnished by Aerojet.

1.3.1.1.4 Facilities. The testing will be accomplished at the Sacramento testing facility of Aerojet General Corporation.

1.3.1.1.5 Test Schedule. The test schedule for the F-1 development tests is shown in Figure 1-2.

1.3.1.2 F-2 Test Plan

See Section 4.0 of Volume V for the F-2 detailed test plan.

1.3.1.3 F-3 Test Plan

The F-3 test fixture will be similar in construction to the F-1 and F-2. It will consist of a structural steel framework to which are attached stainless steel fuel and oxidizer tanks, stainless steel helium bottles, and off-the-shelf propellant system components.

The F-3 fixture will be a dual-purpose testing tool. It will be used initially to test the propellant system of the SPS. Upon completion of this test program, the F-3 will be used to support the engine simulated altitude qualification program.

During the propellant system development tests, a simulated engine will be attached to the test fixture. The simulated engine will consist of solenoid valves which will replace the rocket engine injector valves and a flow and pressure control device which will provide an equivalent engine back pressure. The testing of the F-3 SPS propellant system will involve the use of simulated propellants as well as off-the-shelf components.

The Aerojet SPS engines will be tested in conjunction with the F-3 during the simulated altitude qualification test program at AEDC.

1.3.1.3.1 Objectives. The testing of the F-3 propellant system will accomplish the following objectives:

1. Provide experimental evaluation of the integrated system and its components and subsystems.

2. Prove design concepts and resolve design difficulties

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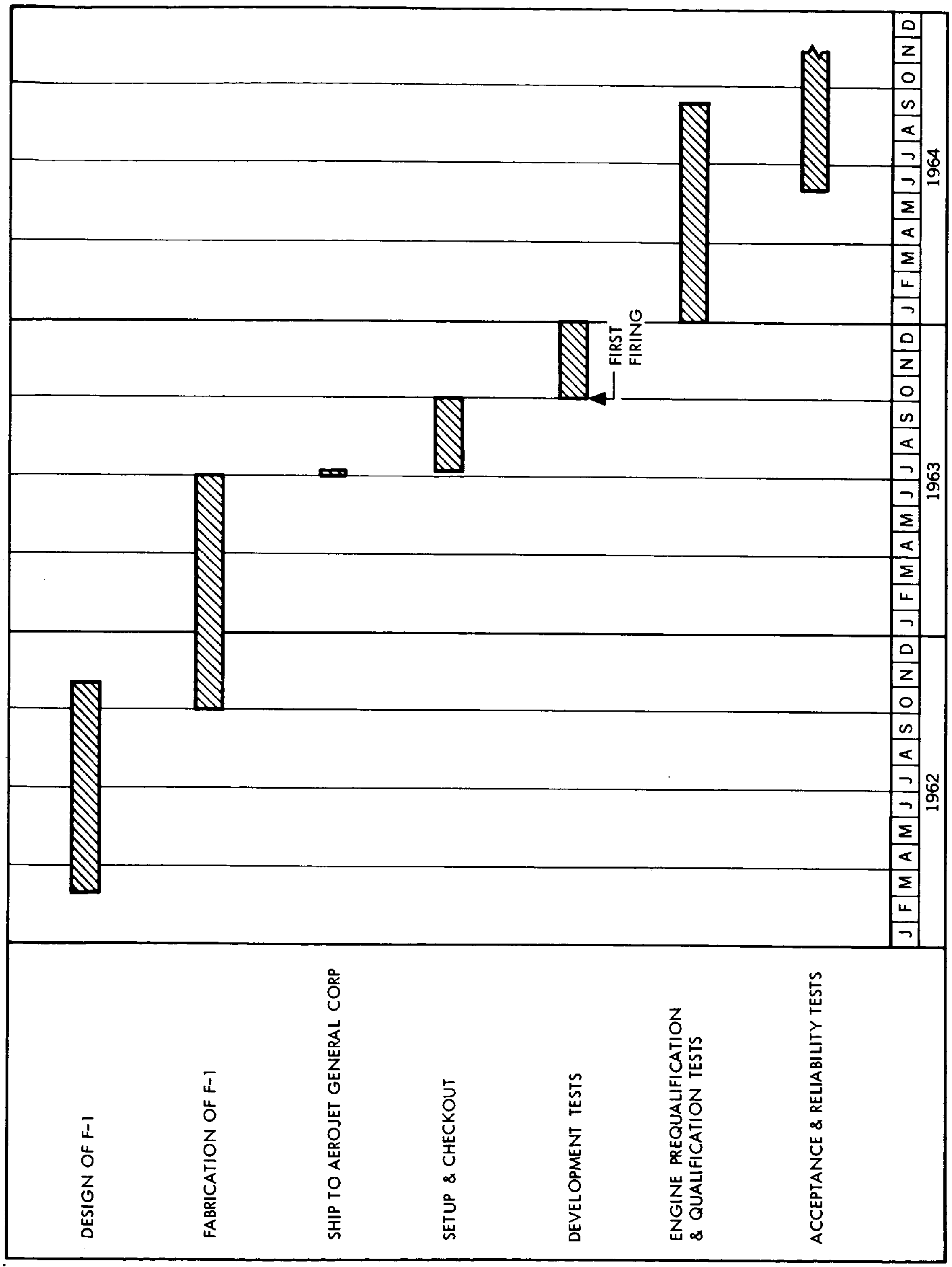

Figure 1-2. Test Fixture Test Schedule

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3. Familiarize design and test personnel with the assembled system and ensure compatibility of components

4. Establish plumbing and component assembly techniques

5. Establish system check-out procedures

1.3.1.3.2 Test Plan. The three general types of tests that will be conducted on the F-3 propellant system are as follows:

1. Evaluation of the system during normal operation

2. Investigation of the system during off-limit operations

3. Investigation of plumbing and component assembly techniques

During the conduction of the above types of tests, techniques covering the filling, draining, and purging of the system will be evaluated.

1.3.1.3.2.1 Data Requirements. During the above tests of the SPS propellant system, the following information list will be monitored and recorded:

1. Pressure of gas in helium tank

2. Temperature of gas in helium tanks

3. Regulator inlet pressure

4. Regulator outlet pressure

5. Pressure of water at exit of oxidizer tank

6. Pressure of water at exit of fuel tank

7. Pressure at inlet of PU subsystem

8. Pressure at exit of PU subsystem

9. Displayed quantity of water in oxidizer tank

10. Actual quantity of water in oxidizer tank

11. Displayed quantity of water in fuel tank

12. Actual quantity of water in fuel tank

13. Propellant utilization valve positions

14. Pressure at inlet to simulated rocket engine injector valves

15. Flow rate of water in oxidizer lines

16. Flow rate of water in fuel lines

17. Lapse time of test runs

1.3.1.3.2.2 Test Procedures. A detailed test procedure will be developed for each of the types of tests outlined in the foregoing paragraph 1.3.1.3.2. In certain cases, it may be advantageous to conduct certain steps of different procedures concurrently or subsequent to each other rather than during widely-separated phases of the test schedule. The scheduling of these steps will be accomplished at a later date.

1. Procedure for the evaluation of the system during normal operation

   All tests will be conducted at existing ambient conditions; no attempt will be made to simulate flight environments. Individual system components will be tested for proof pressure, leakage, and functional capability before installation in the test system.

   Before the system is filled with the fluid media, the test set-up will be checked to verify conformance with the system schematic, tightness of tubing connections, continuity in electrical systems, and adequacy of support for all components and plumbing. The fuel tanks and oxidizer tanks will be filled with water. The helium storage tank (and consequently the whole system) will be pressurized initially to 170 psig with nitrogen or helium. The system will be checked for leakage. The pressure in the helium tank will then be increased to 4500 psia. Initial pressure and temperature readings will be recorded, and the recording instruments will be started.

   The simulated rocket engine injector valves will be actuated, and the pressurized water will be fed through the system for 10 seconds. The recorded data and the test set-up will be checked for discrepancies; sufficient testing will be accomplished to verify satisfactory operation.

[redacted]

The system will then be subjected to 20 cycles of operation. Each cycle will consist of a 1-second period of energizing the injector valves and a following shutdown period of 10 seconds. The recorded data and system will be checked for discrepancies. Sufficient testing will be accomplished to verify satisfactory operation.

The injector valves will then be energized for periods of 20, 30, 40, 50, 60, and 68 seconds, respectively. If discrepancies in data arise during any of the foregoing tests, the individual test will be repeated until the problem has been defined and corrected.

2. Procedure for the evaluation of the system during off-limit operation

Upon satisfactory completion of the foregoing normal operation tests, the system will be subjected to a number of off-limit operation tests to determine the effects of off-design conditions on the over-all performance of the system. A few of the possible off-limit conditions are listed below:

a. Above-normal helium pressure - This condition can result from a second stage failure of either or both of the regulators. The regulator can fail OPEN, permit helium leakage by the seat, or provide a high outlet pressure because of a change in setting.

b. Below-normal helium pressure - This condition can result from a change in regulator setting or the introduction of a restriction in the feed lines.

c. Below-normal helium flow - This condition can result from any of the following components failing CLOSED: solenoid valve, regulator, or check valve. Similarly, any restriction in the line can result in below-normal helium flow.

d. Below-normal propellant flow - This condition can result from a failure of a propellant utilization valve or the introduction of a restriction in the feed lines.

Each of the conditions mentioned in the foregoing outline will be simulated during system testing. To thoroughly check the performance of the propellant system during these off-design conditions, the system will be tested as described below for each of the off-design conditions.

The system will be prepared for testing as previously described. The simulated rocket engine injector valves will be actuated, and the pressurized water will be fed through the system for 10 seconds. The recorded data will be checked, and the test will be repeated a minimum of three times. The system will then be subjected to 20 cycles of operation. Each cycle will consist of a 1-second period of energizing the injector valves and a following shutdown period of 10 seconds. After checking the data, the test will be repeated a second time. The injector valves will then be energized for 70 seconds. This test also will be repeated a second time after the recorded data.

Additional individual tests will be added to the program as system operating characteristics become known and as problems arise during the testing.

3. Procedure for the investigation of plumbing and component assembly techniques

The components are joined to plumbing, and plumbing details will be joined to each other by a method to be developed at the laboratory level. The method will be evaluated by assembling and disassembling joints while the components and plumbing are installed on the F-3 test fixture. The propellant system will have an estimated fifty individual assembly joints. Each joint will undergo at least one assembly and disassembly cycle. Selected joints will be assembled and disassembled as many as six times. The following procedure will be followed during an individual assembly and disassembly cycle:

a. The mating tube ends will be fabricated, cleaned, and inspected in accordance with methods previously developed during the laboratory tube-joint test program. Any weaknesses in the recommended methods will be reported, and improvements will be investigated.

b. Commercial or laboratory developed tools and fixtures will be employed to join the tube ends.

c. The joint will be subjected to a pressure of 1.5 times the operating pressure for 5 minutes at room temperature, using helium as the fluid. A visual inspection will be made for evidence of permanent deformation.

[redacted]

d. The joint will be subjected to operating pressure for 5 minutes, using helium as the fluid. Leakage will be measured by a mass spectrometer probe that will be calibrated before each day's use and have a minimum sensitivity of 10^{-9} st. cc he/sec. In addition, a leakage test at 50 psi and room temperature will be conducted for a period of 5 minutes on all mechanical fittings (other than brazed or welded) designed so that sealing is assisted by internal pressure.

e. Commercial or laboratory developed tools and fixtures will be employed to disassemble the joint.

f. The joint will be thorougly inspected to determine if the disassembly method contaminated the system or permanently damaged the joint ends.

1.3.1.3.3 Equipment Requirements. The equipment required to accomplish the objectives of the test program will include a test stand; pressure, temperature, and flow-sensing elements; indicating and recording equipment; and miscellaneous support equipment.

The test stand will be a structural steel framework to which are attached helium and propellant tanks constructed to ASME codes. Numerous off-the-shelf components that make up the pressurization and propellant distribution subsystems will be included. Propellant receiving tanks will be installed with solenoid valves that simulate the rocket engine injector valves. The propellant utilization subsystem will be designed and fabricated by a subcontractor.

A general list of the types of sensing elements, recording equipment, and miscellaneous equipment required for the test program follows:

1. Pressure transducers, 0 to 500 psig and 0 to 7500 psig
2. Liquid flow transducers, strain-gage type, 0 to 250 gpm
3. Thermocouple probes, stainless steel jacketed, 0 to 300 F
4. Modules, transducer range balance and calibration control, 0 to 15 v dc
5. Amplifiers, wide-band differential, dc-35 kc
6. Galvanometers, optical recording, dc-135 cps

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7. Galvanometers, wide-band recording, dc-5 kc frequency response

8. Oscillators, time-base function generator, 0 to 1 kc

9. Oscillographs, direct-write recorder, 18 channels (maximum)

1.3.1.3.4 Facilities. A special test area will be prepared at the S&ID facility in Downey, California.

1.3.1.3.5 Test Schedule. The test schedule for the F-3 propellant system development tests is shown in Figure 1-3.

The combined test schedule for the F-1, F-2, and F-3 propellant system development test is shown in Figure 1-4.

1.3.1.4 Zero- and Low-Gravity Behavior and Management of SPS Propellant

1.3.1.4.1 Objectives. This test will experimentally determine the SPS propellant behavior during zero- and low-gravity portions of the Apollo mission. Test results will allow the proper design of propellant tankage and programming of mission maneuvers (such as propellant settling, vehicle rotation reorientations) for optimum system performance. The conditions under which liquid propellant is displaced from the bottom of the tank will be established. Using this information, it may be possible to predict the location of the propellant during various phases of the mission. Propellant management systems such as anti-geysering baffles and propellant retention screens will have their design parameters based on this test. The effects of low-gravity propellant dynamics (geysering, sloshing) on vehicle motion and stability also will be established.

1.3.1.4.2 Test Program.

1. Propellant settling and geysering. Propellant geysering and settling, Figure 1-5, will be evaluated under the range of conditions encountered in the Apollo mission. This study will be performed at 1 g, using a 3/8 scale and a full-scale plexiglass transparent tank in which the propellant Reynolds number is simulated. The liquid will be introduced at the top of the tank from a reservoir with a retention device and templated to control the flow area of the fluid. Various baffling arrangements to prevent geysering will be studied. These tests will be performed in the S&ID Engineering Development Laboratory (EDL) and the KC-135 flying laboratory at Wright-Patterson Air Force Base, Dayton, Ohio, where accelerations of 0.1 and 0.5 g will be exerted for periods of 8 to 15 seconds.

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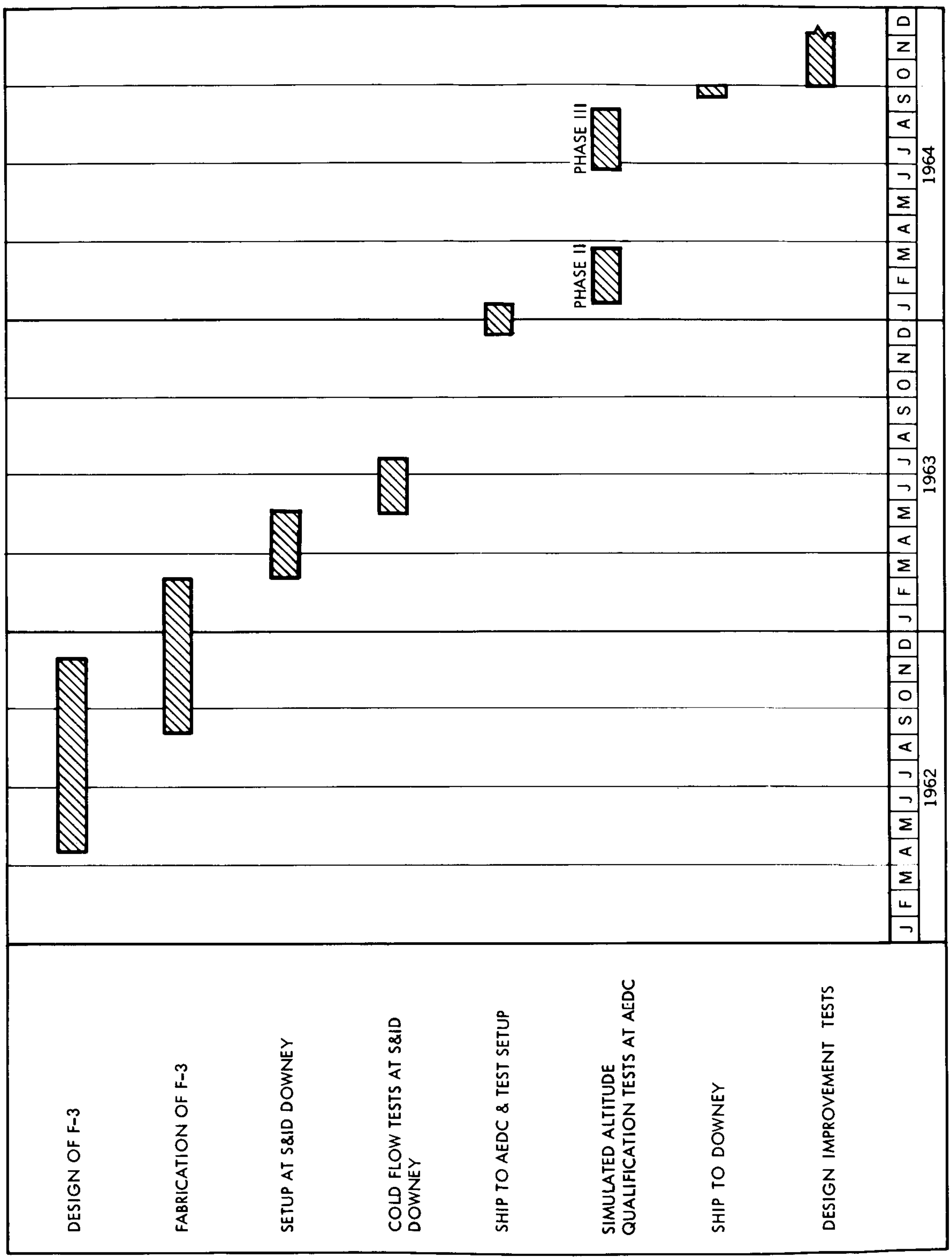

Figure 1-3. F-3 Test Fixture Schedule

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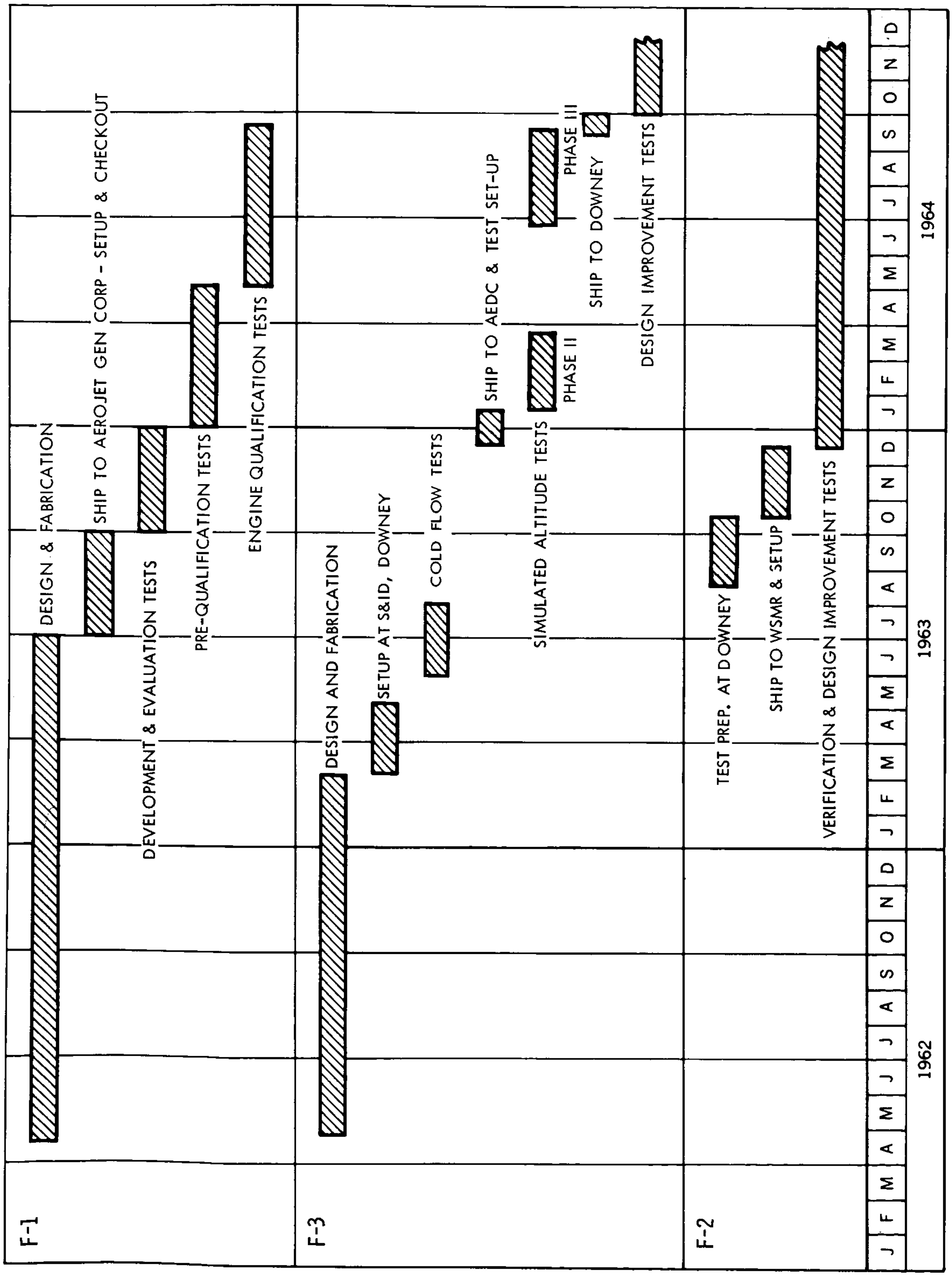

Figure 1-4. F-1, F-2, and F-3 Test Fixtures Combined Schedule

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[redacted]

2. Vehicle maneuvers. The S&ID, EDL drop tower will be used to evaluate SPS propellant behavior during and after vehicle maneuvers. Both angular and translational accelerations will be applied to the model while it is in free fall. A camera, included as an integral part of the test package, will photograph the behavior of the liquid. Transparent plexiglass models 1.32 and 2.64 inches in diameter will simulate the fuel tank and models 1.50 and 3.00 inches in diameter will simulate the oxidizer tank.

   A separate test package will be used in the KC-135 flying zero-g laboratory operated by Wright-Patterson Air Force Base. RCS maneuvers also will be simulated in these tests. Because of the longer period of zero-g in the KC-135, 3- and 5-inch diameter models will be used. Large models also minimize the surface tension effects on propellant sloshing.

   These two tests also will serve as a comparison for the model scaling factors.

3. Retention devices. Several tests are required to demonstrate the effectiveness and reliability of a screen-type liquid retention device. The present considered design is a dense screen that works by the bubble pressure principle. Due to a disturbance, the liquid hydrostatic head is balanced (supported) by the pressure drop required to force a bubble through the screen. The smaller the screen pore size the greater the bubble pressure and the greater the ability to retain liquid.

   For testing, the cylindrically shaped screen will be submerged in water, and a gas feed device within the screen device will be pressurized until the first bubble appears. The screen must also be dynamically tested to show its resistance to engine firing and docking jolts. This involves testing the screen device at the maximum possible disturbance acceleration. In addition, the compatibility of the screen with the propellants will be determined over at least a two-week period. Screen flow and clogging characteristics under operating conditions will be studied in a full-scale facility. All tests will be performed at S&ID EDL.

4. Vapor ingestion. Gas tends to pull into the feedout line during low-gravity SPS engine starts, prior to complete draining of the

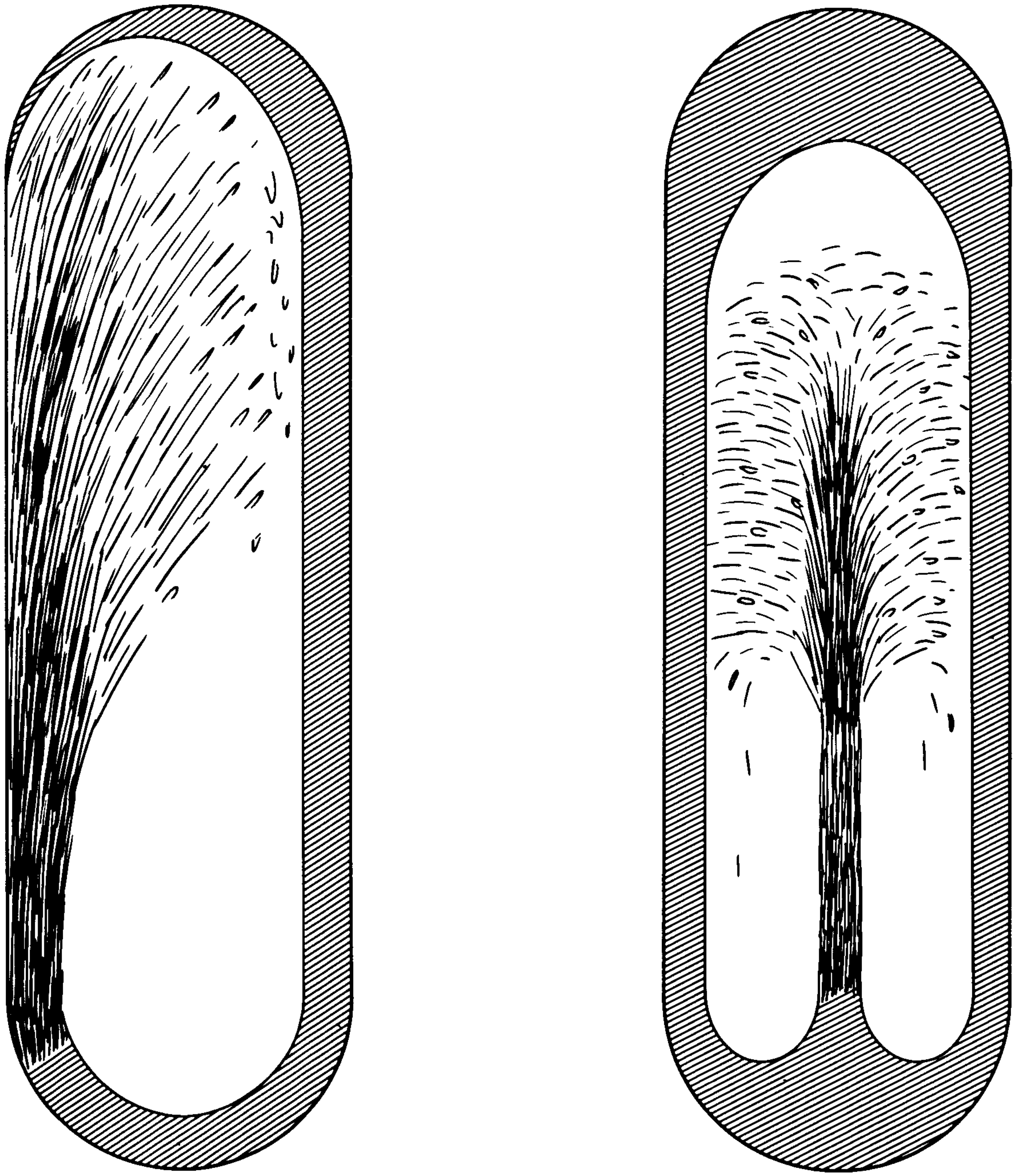

Figure 1-5. Propellant Geysering During Settling Maneuver

propellant tank (Figure 1-6). The conditions under which this pull through occur were experimentally determined. Tests were conducted under standard gravitational conditions, with the results related to actual conditions. Very small scale models, 1/12 scale and smaller, were tested with very high outlet velocities to simulate the SPS Froude' number—ratio of inertial forces to gravitational forces. These tests were conducted at S&ID EDL. Developmental testing will be conducted in the future. The schedule is contingent upon the completion of other tests which will determine basic configurations.

1.3.1.4.3 Equipment. Equipment for all tests performed at EDL will be fabricated there. Equipment for tests to be performed at remote facilities will be self-contained and pretested before shipment to the test location by EDL. No extensive development effort is anticipated in the design of equipment, and where possible, equipment and/or design will be interchanged between tests.

1.3.1.4.4 Facilities. Tests will be performed at the following facilities.

1. S&ID, Engineering Development Laboratories, Downey
   a. Fabrication of test equipment
   b. Vapor ingestion tests
   c. Propellant geysering tests
   d. Retention device development and evaluation
2. Wright-Patterson Air Force Base, Ohio - KC-135 Flying Zero-g Laboratory
   a. Simulation of RCS maneuvers in zero-g environment
3. NAA, S&ID, EDL, Downey, California - Zero-g Drop Tower Facility
   a. Simulation of RCS maneuvers in zero-g environment

1.3.1.4.5 Test Schedule. Test schedule is shown in Figure 1-7.

1.3.1.5 S/M Ullage Transient Pressures

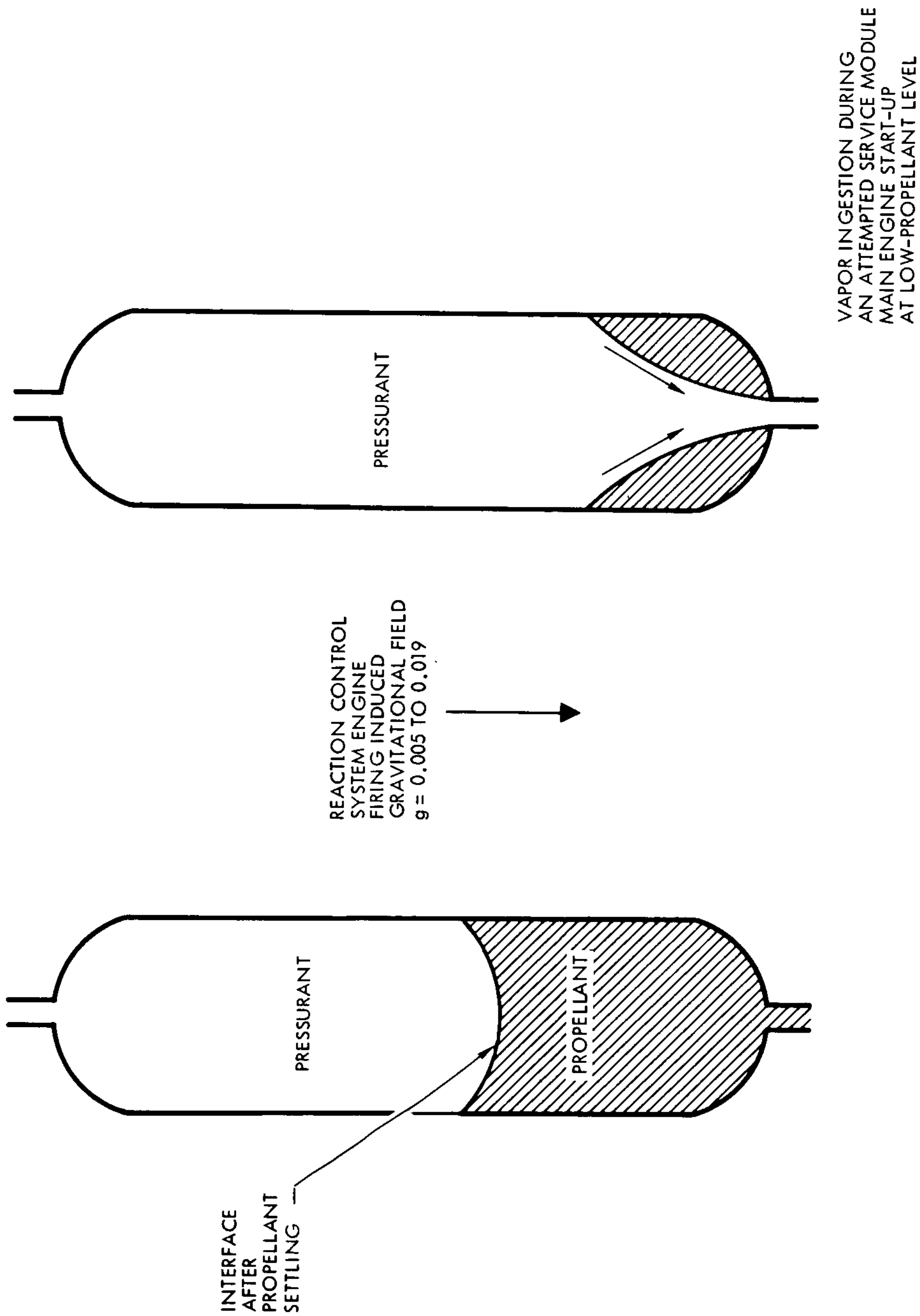

Figure 1-6. Propellant Settling and Vapor Ingestion

1.3.1.5.1 Objectives. These tests determined the magnitude of heat transfer to the ullage and the effect of heat transfer on ullage transient pressures. To meet these objectives, the following were accomplished.

1. The performance of the helium heat exchanger in the fuel and oxidizer lines was evaluated to verify analytic predictions. Any solid formation on the exchanger coil was observed visually, and the results were correlated with inlet helium temperature.

2. The temperature and pressure time history of the ullage gas in a N_2O_4 tank during ullage blowdown was determined.

1.3.1.5.2 Test Plan.

1. Propellant heat exchanger. The test of the propellant heat exchanger used the setup shown in Figure 1-9. Tests were conducted over a range of propellant and helium flow rates and temperatures to verify heat exchanger analysis.

2. Ullage blowdown. The test of ullage blowdown used the test setup shown in Figure 1-10. The following test procedure was used.

   a. Purged the tank and system and partially filled it with N_2O_4, pressurized to each specified test pressure (P_1) with gaseous helium.

   b. Agitated to assure saturation of the helium with the N_2O_4 vapor.

   c. Regulated the flow using the flow orifice (scale the flow according to the quantity of propellant being used).

1.3.1.5.3 Equipment.

1. The following hardware items were required for these tests.

   a. Helium supply and service facilities (procured or leased)

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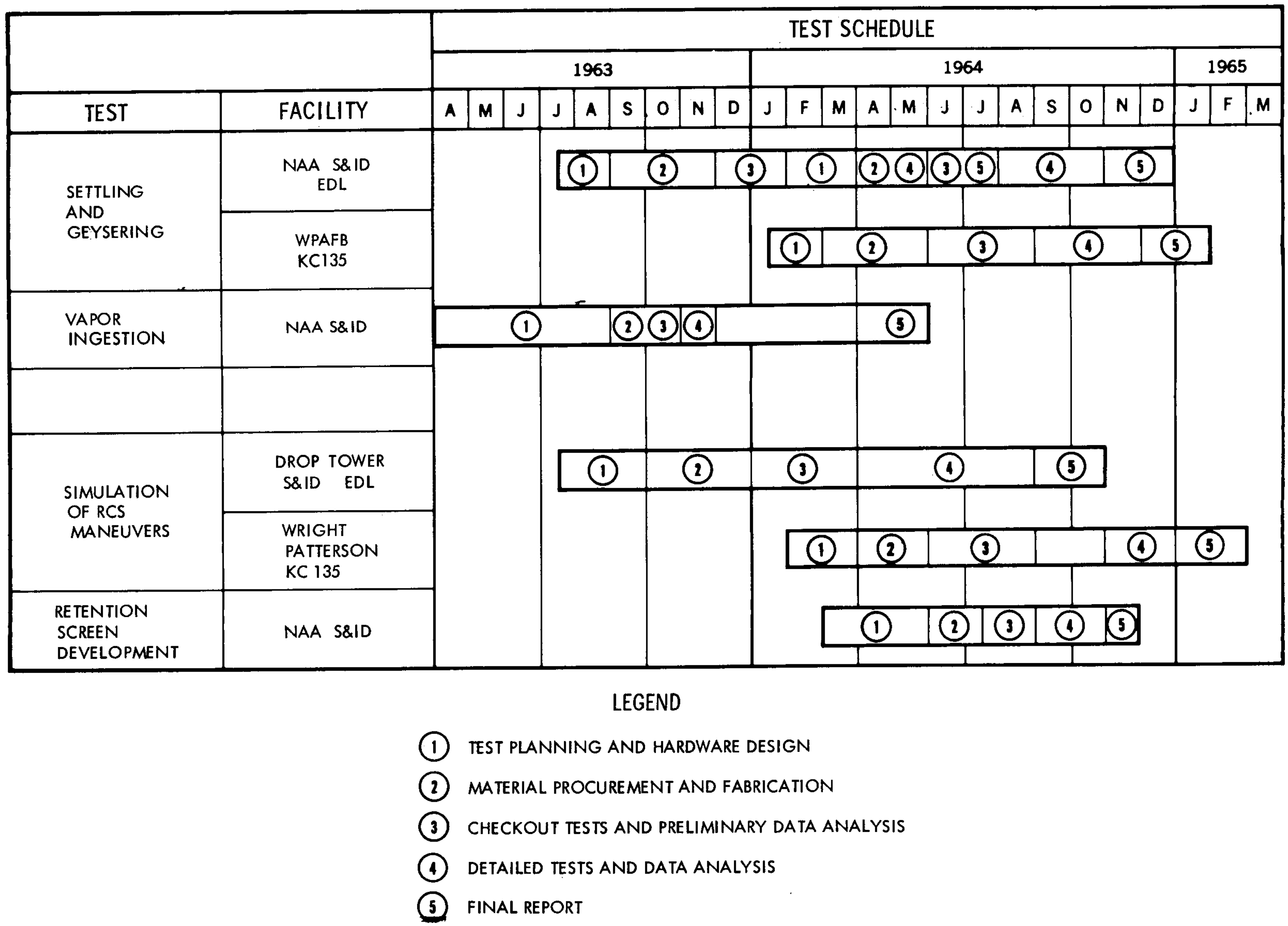

Figure 1-7. Zero- and Low-Gravity Test Schedule

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b. Helium regulator

c. Helium check valve

d. Propellant tank or scale model

e. Low-pressure fuel to helium heat exchanger (lucite exchanger shell)

2. The following instrumentation and recording equipment were required for the tests.

a. Helium temperature thermocouple downstream of pressure regulator

b. Helium flow meter

c. Ullage helium pressure transducer

d. Ullage helium temperature themocouple

e. Propellant flowmeter

f. Helium Δp pressure transducer and Δt sensor across heat exchanger

g. Fuel Δp pressure transducer and Δt sensor across heat exchanger

h. Multi-channel high-speed oscillographs

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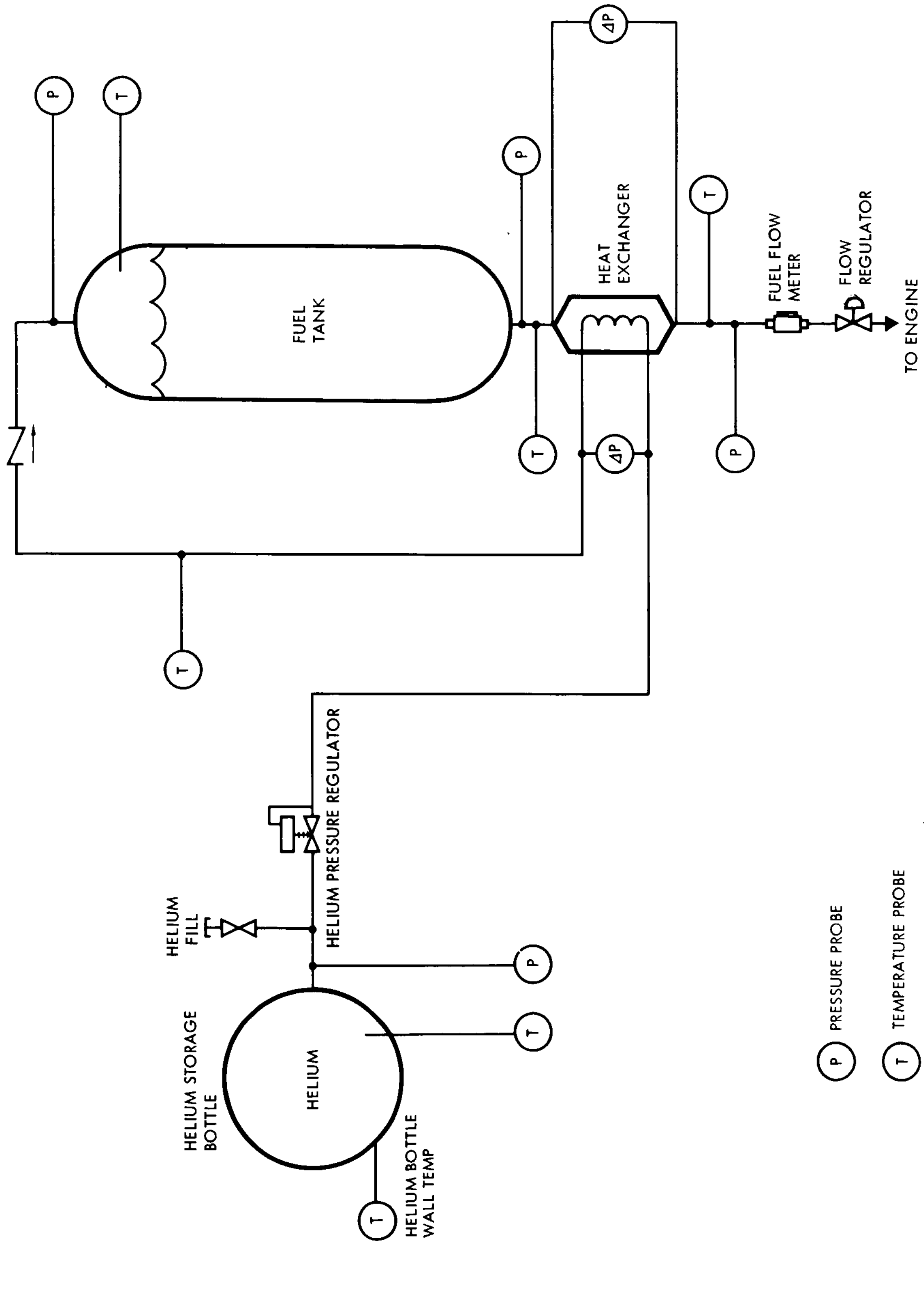

Figure 1-9. Helium-Fuel Heat Exchanger

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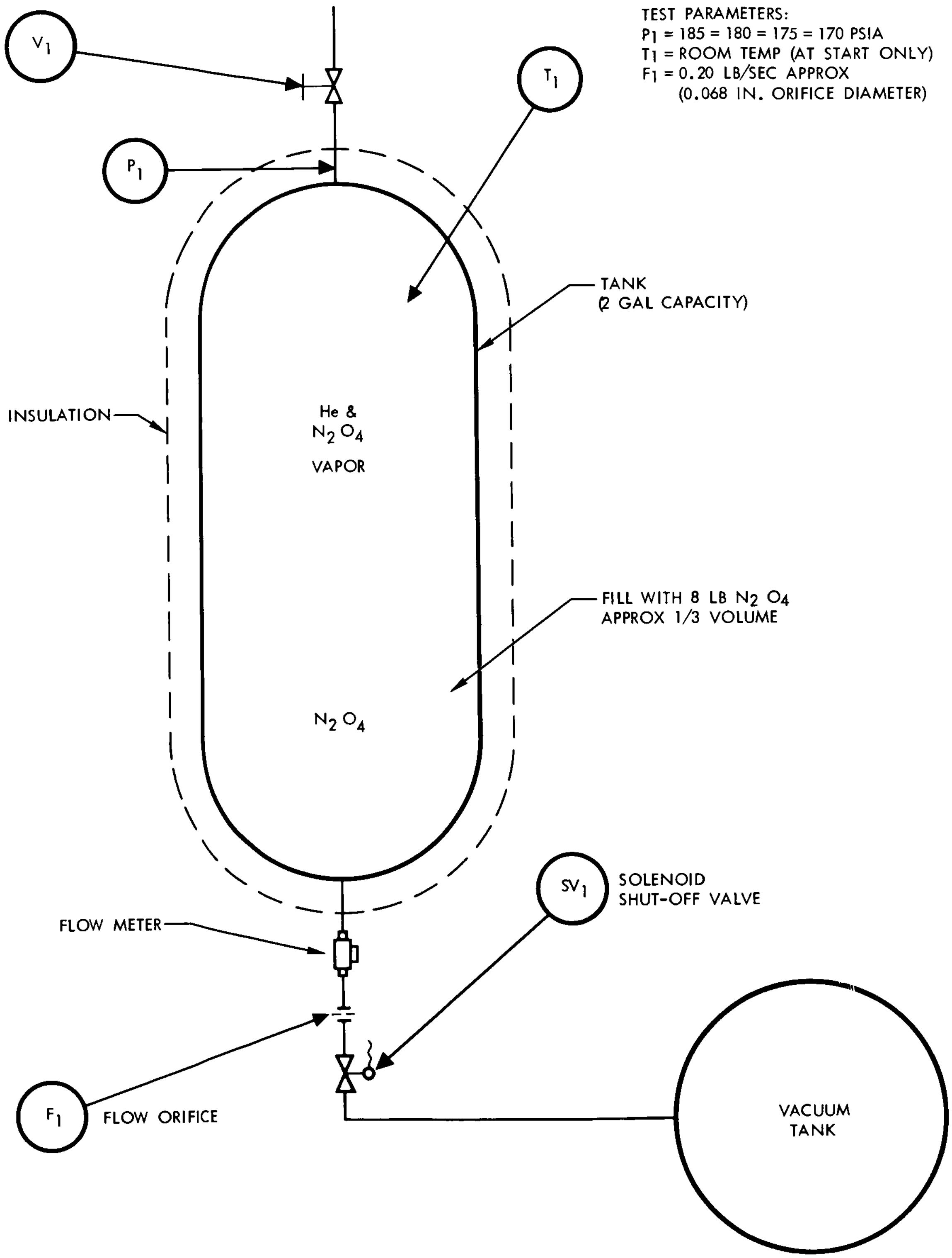

Figure 1-10. Service Module Ullage Test Configuration

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1.3.1.5.4 Facilities. Most of the components used in the test were procured as off-the-shelf items that have already met government specifications. Other components were developed by the S&ID EDL. Standard test facilities available in S&ID EDL were supplemented by recording equipment and auxiliary equipment.

1.3.1.5.5 Test Schedule. The test schedule is presented in Figure 1-11.

1.3.1.6 Surface Heating and Pressure Effects Tests

1.3.1.6.1 Objectives. This test will be used to accomplish the following:

1. Simulate SM/RCS rocket plume interaction with service module surface.
2. Define the pressure.
3. Define the pressure and heat transfer distribution on a flatplate surface immersed in the exhaust plume at simulated space conditions.
4. Obtain correlation between theoretical analyses and test results.
5. Define a satisfactory location for the SM/RCS, with or without plume deflectors, considering surface heating and side thrust.
6. Demonstrate the operation of the integrated RCS at the maximum obtainable altitude environment.
7. Obtain data on the effect of the RCS plume impingement on samples of the actual radiator surface.

1.3.1.6.2 Test Plan. The test plan consists of three phases.

1. Phase I test activity will consist of a checkout of vacuum cell capability with the operation of a rocket engine using hypergolic propellants, feasibility study of techniques for flow-field and shock visualization, and qualification of plate pressure and temperature instrumentation.
2. Phase II testing will consist of a parameteric study of the surface-heating rate and pressure distribution at various nozzle cant angles and nozzle heights above the test plate, a study of the

[redacted]

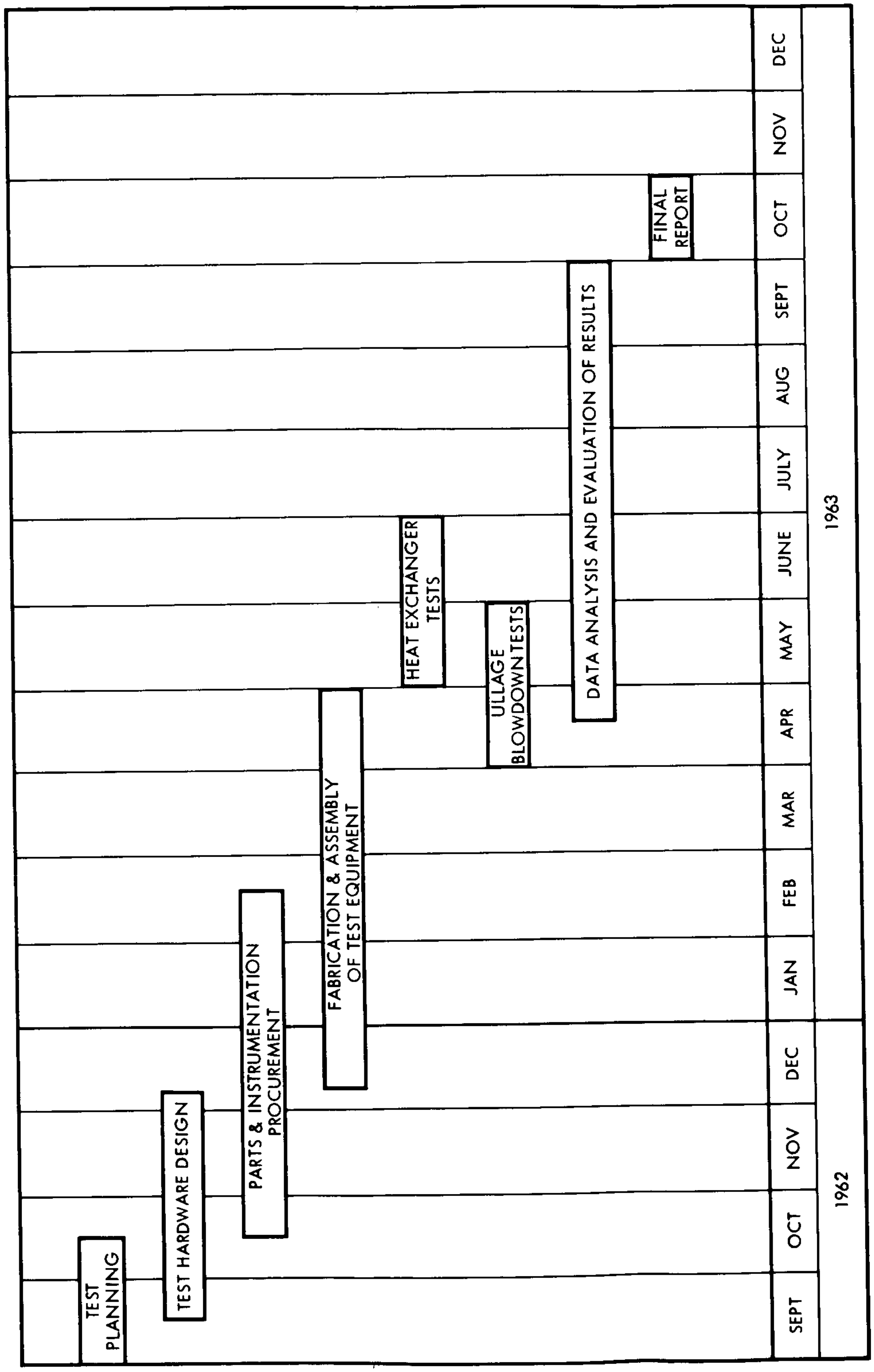

Figure 1-11. Service Module Ullage Transience Test Schedule

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effect on surface heating and pressure and deflector designs, and a study of the effect of exhaust plume impingement on the radiatior surface.

3. Phase III testing will study the operating characteristics of the integrated RCS at the maximum available altitude and the effect of the radiation reflector on the rocket motor life.

1.3.1.6.2.1 Test Requirements. The RCS space exhaust plume will be simulated at available vacuum cell conditions by reducing the area ratio of the nozzle to the point where the initial inclination angle of the flow issuing from the exit equals that in space. To determine the effect of reducing the area ratio, several area ratio-vacuum cell conditions will be tested. The degree of simulation will be checked with flow-field and shock-pattern visualization techniques.

The integrated RCS will be tested for thrust build-up and ignition characteristics, engine life, and complete system operation at maximum available altitudes.

1.3.1.6.2.2 Data Requirements.

1. Surface temperature versus time

2. Surface static pressure versus time

3. Flow-field and shock-pattern visualization

4. Radiator sample temperature, absorptivity, emissivity, and surface mechanical condition versus time

5. Rocket engine: Pc, Wf, Wo, Pinj, P tank, thrust, total running time

1.3.1.6.2.3 Data Reduction.

1. Pressure and temperature distribution for various area ratios, nozzle-to-plate distances, and cant angles

2. Test-plate heat transfer distribution for various area ratios, nozzle-to-plate distances, and cant angles

1.3.1.6.2.4 Analysis. The test-plate heat transfer and pressure data will be analyzed to develop correlation between test data and theoretical analysis. The flow visualization will be used to determine the degree of shape simulation to correlate test configurations.

[redacted]

1.3.1.6.3 Equipment. The following equipment will be required.

a. Rocket motors with four different area ratio nozzles (10, 15, 20, 40) and propulsion support system (heavy hardware and integrated RCS system), flat-plate instrument surface, radiator samples, and deflector

b. Heat transfer instrumentation capable of 1.0 to 26.0 Btu/ft^2/sec and high response, pressure instrumentation capable of 1.0 psia and high response

c. Equipment for testing optical properties of radiator surface coatings after exposure during RCS test

1.3.1.6.4 Facilities. The J2A Test Cell at AEDC, Tullahoma, Tennessee, will be used to achieve the desired test conditions. The capability of the cell is expected to be at least 300,000 ft.

1.3.1.6.5 Schedule. Figure 1-12 presents the schedule for surface heating and pressure effects tests.

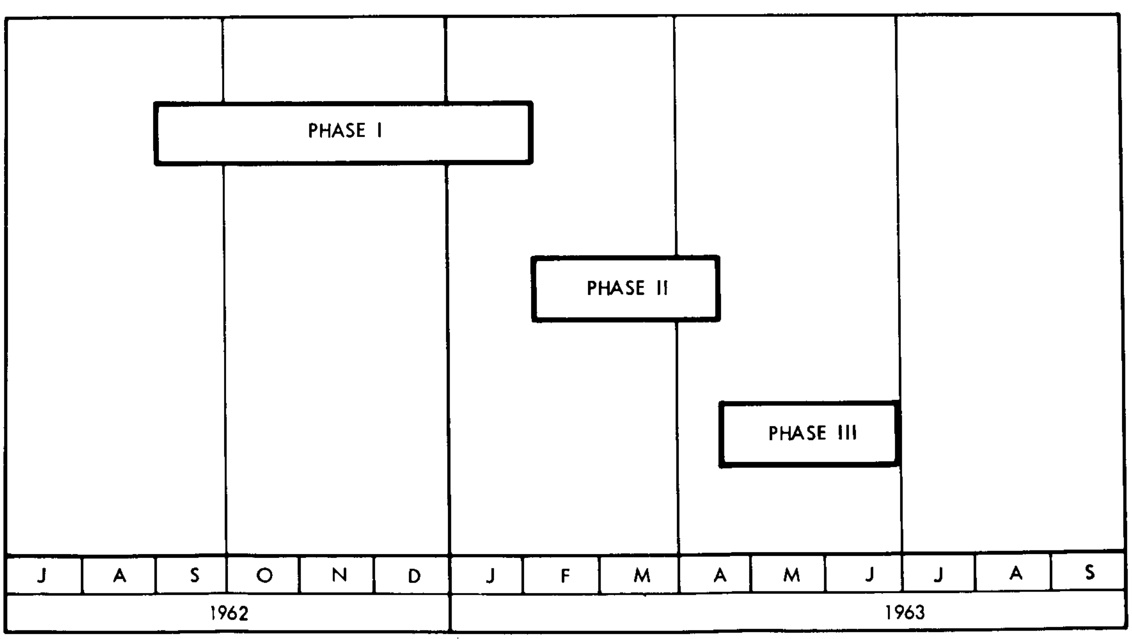

Figure 1-12. Test Schedule for Surface Heating and Pressure Effects Test

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2.0 REACTION CONTROL SYSTEM

2.1 SCOPE

The RCS for the command module and service module development program will include engineering development, evaluation, and design verification tests conducted by the subcontractor and S&ID. Qualification tests will be conducted in accordance with procedures described in SID 62-109-3. The subcontractor development test program consists of experimental tests and prototype development tests. The development tests program of S&ID consists of different phases of tests at the breadboard level to determine subsystem compatibility, to verify component supplier's test results, and to evaluate the system before the integrated system tests.

2.2 SUBCONTRACTOR TEST PLAN

2.2.1 <u>Marquardt Test Plan</u>

2.2.1.1 Objective

The primary objective of the subcontractor's test plan is to develop and verify the design configuration of the Apollo spacecraft reaction control system. This objective will be accomplished by developing the system in a logical sequence and will culminate in a final design capable of meeting the high standards of reliability required for Apollo spacecraft.

2.2.1.2 Test Plan

The development test plan is divided into two major phases of development and design verification testing: experimental tests and prototype development tests.

2.2.1.2.1 <u>Experimental Test Plan</u>. The purpose of the experimental test plan is to establish the detail design criteria for the prototype design and to determine the optimum component configuration.

Various injectors will be investigated and tested to determine the optimum configuration compatible with short-pulse performance, steady-state performance, and engine-life considerations.

Tests will be conducted to establish the optimum combustion chamber geometry with consideration of life and performance requirements. This program will include developmental investigations to determine the minimum practical chamber weight that will result in a low-heat capacity chamber and thus reduce the required heat sink capacity of the injector head at engine shutdown.

2.2.1.2.2 Prototype Development Test Plan. This test plan will include minimum-impulse performance tests, life tests, and environmental tests on individual components and/or the complete prototype engine. The results of these tests will probably precipitate design modifications. The final design will then be recycled through the development test program.

2.2.1.2.2.1 Thrust Chambers. Material evaluation (sea level and altitude) and coating evaluation (sea level and altitude) tests will be conducted on the thrust chambers.

2.2.1.2.2.2 Propellant Solenoid Valves. The following tests will be conducted on the injector solenoid valves.

1. Steady-state tests, including flow versus pressure drop across the valve, and leakage and proof-pressure tests

2. Dynamic response tests matching opening and closing time, using minimum and maximum voltage

3. Cycling test (minimum of 100,000 cycles at heat-soak temperatures)

4. Temperature extremes (to specification), excluding those conditions in cycling tests

5. Vibration tests

6. Vacuum and propellant soak tests

7. Radio interference tests

8. Explosive atmosphere tests

9. Burst-pressure tests

2.2.1.2.2.3 Injector Heads. The following tests will be conducted on the injector heads.

1. Pressure tests, including leakage and proof-pressure tests

2. Flow tests of fuel and oxidizer throughout the flow and differential pressure range

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3. Total flow tests determining proper spray distribution

4. Spray-impingement tests determining proper spray impingement and no excessive breakthrough of either oxidizer or fuel streams

5. Burst-pressure tests

2.2.1.2.2.4 Rocket Engine Tests. Rocket engine tests will include the following:

1. Nominal steady-state and minimum-impulse performance, i.e., thrust, efficiency, propellant flow, nominal oxidizer-to-fuel ratio (O/F) and off O/F ratios

2. Reliable life tests (sea level and altitude) with mission cycle tests, including temperature and heat soak-back and test to failure

3. Attitude tests, vertical upward, and horizontal tests will be conducted and compared to vertical downward tests. These tests will include starts, repetitive starts, minimum impulse, and steady-state performance.

4. Pulse-modulation tests

5. Supply pressure variation tests including propellant depletion tests

6. Limited environmental tests

7. Burst-pressure tests

2.2.1.3 Equipment

The test facility will be equipped with remote controls, environmental simulation equipment, thrust measuring equipment, and high response recording and measuring instruments.

2.2.1.4 Facilities

The development tests of the S/M reaction control engines will be performed at Marquardt Jet Laboratory in Van Nuys, California. The test facility is equipped to run sea-level and altitude simulation tests. Chambers will be located at the test facility to produce altitude pressure simulation of 10^{-5} mm Hg for 100-millisecond runs and 0.02 psia for continuous runs.

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2.2.1.5 Subcontractor Test Schedule

The subcontractor test schedule is shown in Figure 2-1.

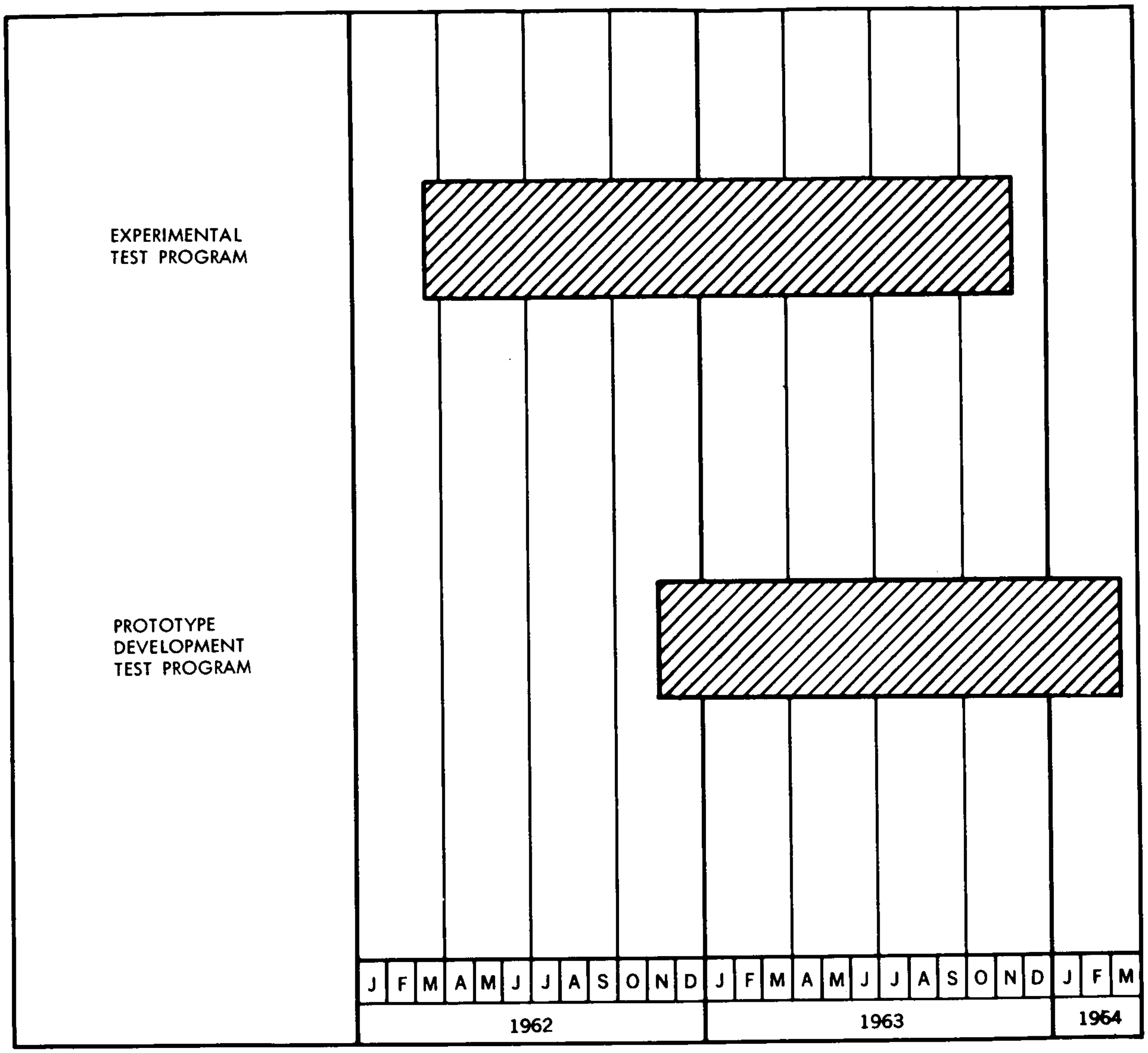

Figure 2-1. Reaction Control System Subcontractor (Marquardt) Test Schedule

2.2.2 <u>Rocketdyne Test Plan</u>

2.2.2.1 Objective

The primary objective of the subcontractors test plan is to verify the design configuration of the Apollo command module reaction control engines in compliance with the requirements of S&ID Procurement Specification MC-901-0067A.

[redacted]

2.2.2.2 Test Plan

Development of the Apollo command module RCS engines will be based on the Gemini 100-pound thrust orbit attitude and maneuvering system (OAMS) reaction control engines. The development test program is divided into two phases: experimental tests and prototype development tests.

2.2.2.2.1 Experimental Test Plan. The experimental portion of the plan, conducted concurrently with the prototype test plan, will be used to fabricate and test preliminary and backup designs. Various propellant valve problems, such as corrosion, leakage, response time, and excessive pressure losses in the internal passages, will be investigated during the experimental test program.

Thrust chamber heat transfer, char rate, performance characteristics, and endurance testing will be investigated. Assembly techniques and materials providing superior performance while maintaining minimum weight will be determined.

2.2.2.2.2 Prototype Development Test Plan. The prototype development test plan has been initiated with pulse-type tests, which have been demonstrated to be more detrimental on ablative chambers.

2.2.2.2.2.1 Thrust Chambers. Material evaluation and effect of operating and environmental conditions on thrust chamber life, heat transfer rates, and char rates are currently being tested.

2.2.2.2.2.2 Injector Solenoid Valves. Tests are being conducted to determine proof pressure, leakage, water calibration, insulation resistance, dielectric strength, coil resistance, power consumption, response time, and endurance (cycling) under sea level and altitude conditions.

2.2.2.2.2.3 Rocket Engine Tests. Rocket engine tests will include the following:

1. Engine durability will be demonstrated through a series of mission cycle tests. Particular attention will be given to adequacy of ablative wall thickness with respect to char depth and maximum sock-back temperature.

2. Engine performance will be demonstrated at rated and off-nominal conditions.

[redacted]

3. Engine operating-characteristics testing will define the start, restart, and cutoff transients under pulsing conditions. Minimum impulse bit characteristics will be obtained.

4. Engine heat transfer as a function of pulse length and run time will be determined.

5. Actual safe operating limits of the engine system will be determined by overstress testing. Minimum and maximum safe operating points of temperatures, pressures, thrust, mixture ratio, engine voltage, shocks, vibration, and corrosion will be demonstrated.

6. Malfunction simulation testing will demonstrate the ability of the engine to complete the mission safely in the event of a malfunction, such as off-mixture ratio, excessive propellant inlet pressures, and excessive propellant and hardware temperatures.

2.2.2.3 Equipment

The test facility will be equipped with remote controls, environmental simulation equipment, thrust measuring equipment, and ultra-high response recording and measuring instruments.

2.2.2.4 Facilities

The development of the command module reaction control engines will be accomplished at the Rocketdyne Canoga Plant Development Laboratory and the Rocketdyne Propulsion Field Laboratory. Facilities to conduct component environmental tests are located in the Development Laboratory. The Propulsion Field Laboratory has facilities equipped to fire the engines at both sea level and altitude. The altitude environment capability is 100,000 feet and 200 F.

2.2.2.5 Subcontractor Test Schedule

The Rocketdyne test schedule is shown in Figure 2-2.

2.3 S&ID TESTS

2.3.1 Breadboard Testing of Apollo Command Module RCS

2.3.1.1 Objectives

The breadboard testing of command module reaction control system will accomplish the following objectives:

1. Provide experimental evaluation of the integrated system

2. Prove design concepts

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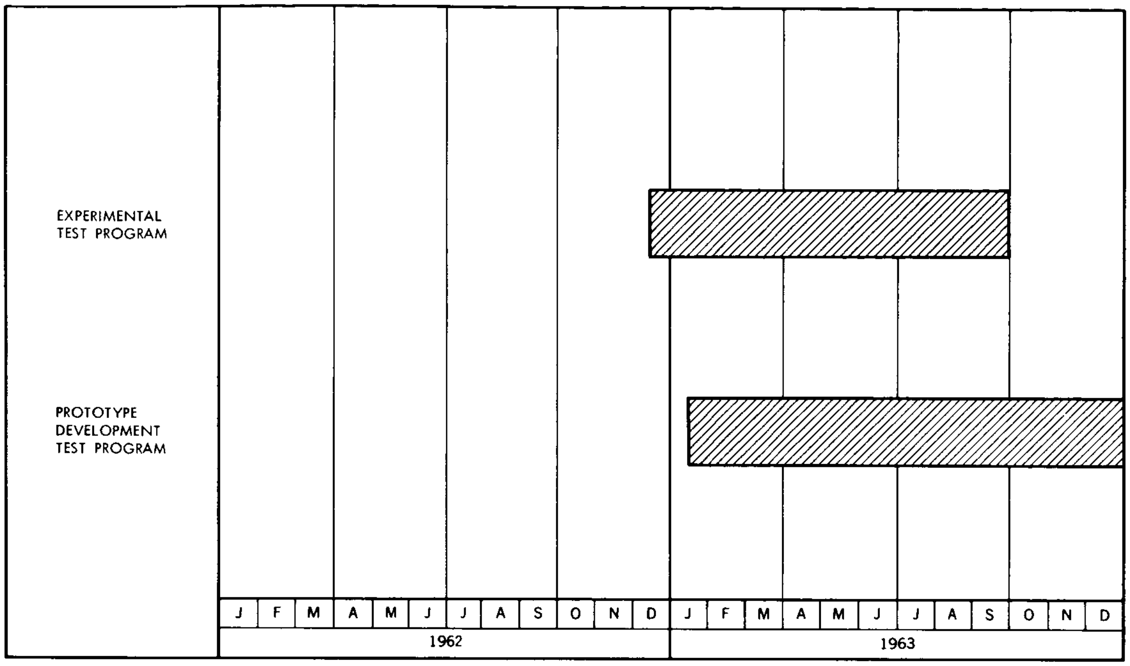

Figure 2-2. Reaction Control System Subcontractor (Rocketdyne) Test Schedule

3. Resolve design difficulties
4. Ensure compatibility of components
5. Provide data for system calibration
6. Resolve propellant handling techniques
7. Verify the suitability of the system for its ultimate use

2.3.1.2 Test Plan

The testing of the breadboard system will be divided into three progressive phases. The major differences in the test phases will be in the types of components used in the test setups and in the fluid media used during the test runs. Phase I testing will employ available off-the-shelf components that will fulfill the preliminary design requirements. The fluid media to be used during Phase I will be water and nitrogen.

Phase II components will be flight articles that satisfy the requirements of S&ID equipment specifications but which have not completed qualification testing. Phase III components will be fully-qualified flight articles. The fluid media to be used during Phase II and Phase III testing will initially be distilled water and will ultimately be hypergolic propellants.

2.3.1.2.1 Data Requirements. During the testing of the command module RCS, the following list will be monitored and recorded:

1. Pressure of gas in helium tank
2. Temperature of gas in helium tank
3. Inlet pressure of regulator No. 1
4. Inlet pressure of regulator No. 2
5. Outlet pressure of the primary stage of regulator No. 1
6. Outlet pressure of the primary stage of regulator No. 2
7. Outlet pressure of the secondary stage of regulator No. 1
8. Outlet pressure of the secondary stage of regulator No. 2
9. Inlet pressure of the check valves
10. Pressure of gas in fuel tank on gas side of bladder
11. Temperature of gas in fuel tank on gas side of bladder
12. Pressure of fuel in fuel tank on fuel side of bladder
13. Temperature of fuel in fuel tank on fuel side of bladder
14. Pressure of gas in oxidizer tank on gas side of bladder
15. Temperature of gas in oxidizer tank on gas side of bladder
16. Pressure of oxidizer in oxidizer tank on oxidizer side of bladder
17. Temperature of oxidizer in oxidizer tank on oxidizer side of bladder

[redacted] [redacted]

18. Inlet pressure of the oxidizer burst disc
19. Inlet pressure of the fuel burst disc
20. Outlet pressure of the fuel solenoid valve
21. Outlet pressure of the oxidizer solenoid valve
22. Flow rate of oxidizer
23. Flow rate of fuel
24. Engine +P fuel line temperature
25. Engine +P fuel line pressure
26. Engine +P oxidizer line temperature
27. Engine +P oxidizer line pressure
28. Engine -P fuel line temperature
29. Engine -P fuel line pressure
30. Engine -P oxidizer line temperature
31. Engine -P oxidizer line pressure
32. Engine +Y fuel line temperature
33. Engine +Y fuel line pressure
34. Engine +Y oxidizer line temperature
35. Engine +Y oxidizer line pressure
36. Engine -Y fuel line temperature
37. Engine -Y fuel line pressure
38. Engine -Y oxidizer line temperature
39. Engine -Y oxidizer line pressure
40. Engine +R fuel line temperature

[redacted] [redacted]

[redacted]

41. Engine +R fuel line pressure

42. Engine +R oxidizer line temperature

43. Engine +R oxidizer line pressure

44. Engine -R fuel line temperature

45. Engine -R fuel line pressure

46. Engine -R oxidizer line temperature

47. Engine -R oxidizer line pressure

2.3.1.2.2 Test Procedures. The command module reaction control system will consist of two independent systems. The systems will be identified as system A and system B. Both systems will be installed on the test stand to expedite the test program. Off-the-shelf components will be installed on system A for Phase I testing. Components that meet S&ID specifications but have not been qualified will be installed on system B for Phase II testing. During Phase II testing, system A will be reworked to incorporate qualified components for Phase III testing. At the conclusion of Phase II testing, system B will be reworked to incorporate qualified components for Phase III testing. The two systems will be tested during Phase III.

The tests will be conducted at existing ambient conditions of pressure and temperature, with no attempt to simulate flight environments. Safety requirements will be strictly adhered to at all times, especially when nitrogen tetroxide and monomethylhydrazine are being handled, because the propellants are not only hypergolic by nature, but highly toxic as well. Individual system components for Phase I and II testing will be tested for proof pressure, leakage, and compatibility with the applicable fluid medium before installation in the breadboard system.

2.3.1.2.3 Phase I Procedure. The command module reaction control system (see Figure 2-3) will be free from contaminates at all times. All components, tubing, and fittings will be purged and decontaminated prior to assembly as a system. The cleaning process to be used on all components, tubing, and fittings will consist of (1) purge with high-flow, dry, filtered nitrogen, (2) flush with trichloroethylene, and (3) purge again with high-flow, dry, filtered nitrogen. All components, tubing, and fittings will be capped immediately after cleaning and will remain capped until installation into the system. All system access ports and instrumentation ports will either be capped or connected at all times to prevent contamination of the system.

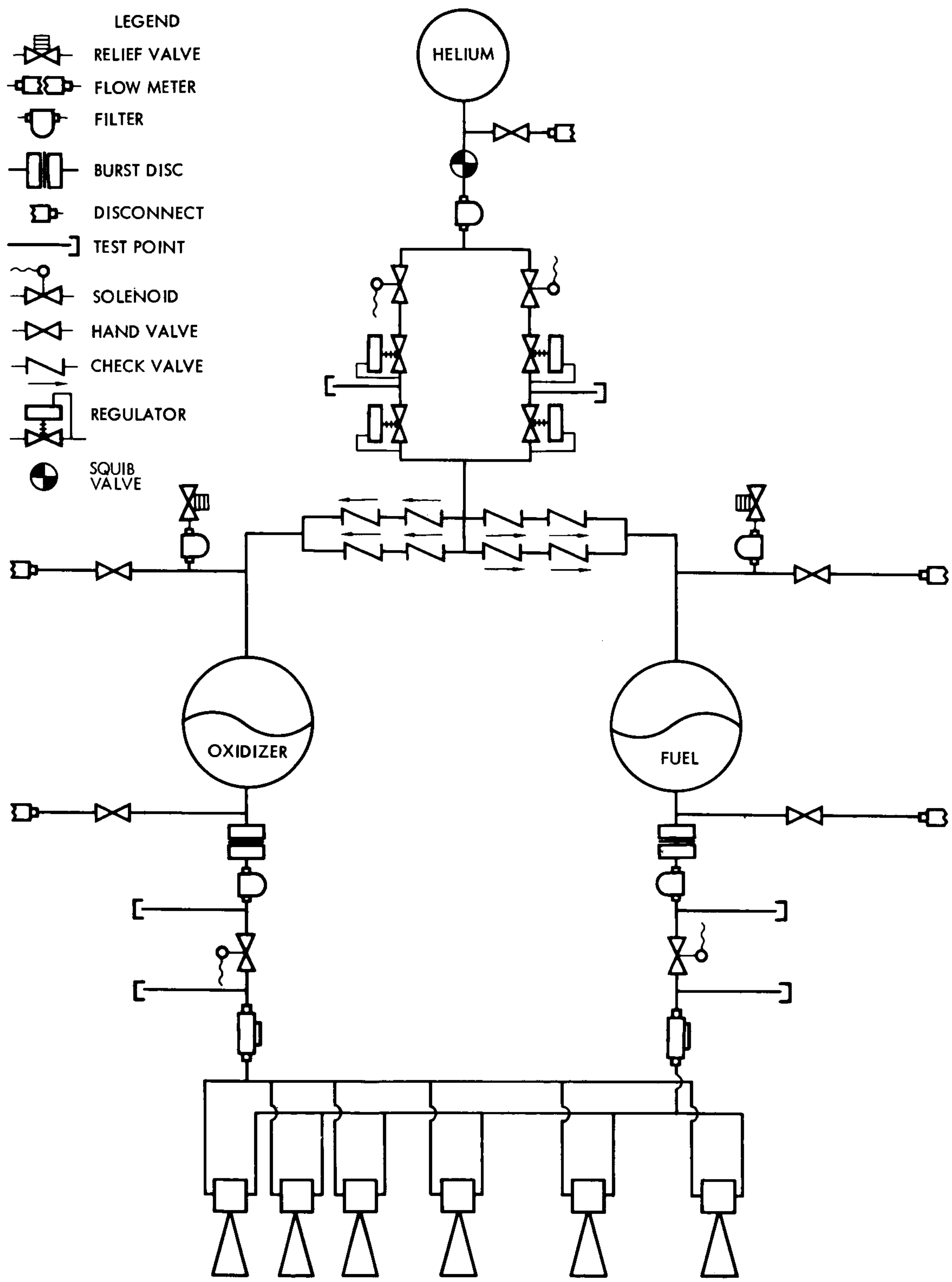

Figure 2-3. Schematic of the Phase 1 Breadboard Command Module Reaction Control System

[redacted]

The following is a list of the pretest conditions to be verified prior to the start of all tests.

1. The system must conform to the test schematic.

2. All plumbing connections must be tight.

3. Electrical wiring must be properly installed.

4. All components must be adequately supported.

5. Instrumentation must be correctly installed.

6. The system shall not leak.

The system test media will be as follows:

1. Nitrogen gas—oil free per specification MIL-N-6011, Grade A, Type I

2. Distilled water having a minimum specific resistivity of 50,000 ohms

The fluid loading lines will consist of clean plumbing and will contain a filter immediately upstream of the test system. The filter will be capable of removing all particles that are larger than 60 microns in size.

At the end of the working day, the system will be depressurized and cleaned. The nitrogen supply system upstream and downstream of the check valves will be carefully depressurized. The propellant tanks and lines will be emptied of water. The system will then be purged and dried with high-flow, dry, filtered nitrogen.

Phase I testing will be divided into two series of tests. Low-response instrumentation will be used during the first series of tests; high-response instrumentation and permanent recording equipment will be used during the second series of tests. Because of the use of low-response instrumentation, the first series of tests will be performed primarily to gain preliminary knowledge of the breadboard system and testing techniques.

Because water will be used in place of the propellants and nitrogen will be used in place of helium during Phase I testing, system temperatures will be monitored during test No. 5 only. The system pressures to be measured during the individual tests are designated in the following detailed descriptions of the tests.

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2.3.1.2.3.1 Test No. 1

Objective. The objective of this test is to determine whether a high differential pressure will cause extrusion of the oxidizer and fuel bladders into the small holes of the tank outlets.

Test Program. After installation of the bladder specimen in a test fixture, pressure differentials from 50 to 500 psi will be applied across the specimen for varying time periods. The specimen will be examined after each pressure test.

2.3.1.2.3.2 Test No. 2

Objective. The objective of this test is to verify that the propellant system and the rocket engines function properly.

Instrumentation. Pressure-indicating instruments will be located at points 3, 4, 5, 6, 7, 8, 10, 14, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, and 47, as designated in paragraph 2.3.1.2.1 (Data Requirements).

System Requirements.

1. A pressure by-pass line will be installed parallel to the squib valve.

2. The propellant tanks will be filled with water.

3. The helium tank will be pressurized to 750 psig with nitrogen.

4. The regulator outlet pressure should read 300 psig at static conditions.

5. All propellant system solenoid valves will be open.

Test Program. A single engine system functional test will be performed by individually actuating the fuel and oxidizer injector valves for five seconds, followed by simultaneous actuation of both fuel and oxidizer injector valves for another five seconds. The test will be performed on each of the six engines.

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2.3.1.2.3.3 Test No. 3

Objective. The objective of this test is to determine the maximum amount of water that can be loaded into each of the propellant tanks and to determine the expulsion efficiency of the bladders.

Instrumentation. Pressure gages will be used to indicate system pressure. The water supply tank will be calibrated to indicate the quantity of water contained within the tank.

Test Program. The volumes of the oxidizer tank and the fuel tank will be determined by filling the tanks individually with a known quantity of water from a calibrated supply tank. The expulsion efficiency of the bladders will be established by forcing the water from the system tanks into the calibrated supply tank and observing the quantity of water expelled.

2.3.1.2.3.4 Test No. 4

Objective. The objective of this test is to determine the flow rate of water through the rocket engine injector valves.

Instrumentation. Pressure-indicating instruments will be located at points 7, 8, 10, 14, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, and 47, as designated in paragraph 2.3.1.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. A pressure by-pass line will be installed parallel to the squib valve.

2. The propellant tanks will be filled with water.

3. The helium tank will be pressurized to 4500 psig with nitrogen.

4. The regulator outlet pressure should read 300 psig at static conditions.

5. With the exception of the engine solenoid valves, all propellant system solenoid valves will be open.

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Test Program. Flow rates through the engine injector valves will be determined by individual actuation of the fuel and oxidizer valves for 15-second periods, followed by simultaneous actuation of both valves for another 15 seconds. The test will be performed on each of the six engines.

2.3.1.2.3.5 Test No. 5

Objective. The objective of this test is to determine the temperature of the helium entering the propellant tanks during the dump sequence of a pad abort maneuver.

Instrumentation. Pressure-indicating instruments will be located at points 1, 7, 8, 10, and 12, as designated in paragraph 2.3.1.2.1 (Data Requirements). Temperature indicating instruments will be located on the exterior of the helium tank, the outlet of the helium tank, the outlet of each regulator, and the inlet and outlet of the fuel tank.

System Requirements.

1. A pressure by-pass line will be installed parallel to the squib valve.

2. The fuel manifold line will be disconnected at the outlet port of the fuel solenoid valve and replaced by a 5/8-in. OD flex hose to which is attached a flow control valve and a flow meter. The flow control valve will be adjusted to maintain a flow rate of 6.8 gpm.

3. The oxidizer line will be disconnected at the outlet of the oxidizer tank and replaced by a flex hose to which is attached a solenoid operated valve capable of handling the required flow rate of 30 gpm. A short dump line will be attached to the solenoid operated valve.

4. The fuel solenoid valve will be closed.

5. The oxidizer dump solenoid valve will be closed.

6. The propellant tanks will be filled with water.

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7. The helium solenoid valves will be closed.

8. The helium tank and the helium system down to the solenoid valves will be pressurized to 4500 psig with helium.

Test Program. The change in temperature of the helium entering the oxidizer and fuel tanks during a simulated pad abort maneuver will be determined by energizing an oxidizer dump solenoid valve and the fuel system solenoid valve in accordance with a predetermined sequence. The flow in the fuel system will simulate the actuation of the fuel injector valves of five engines simultaneously.

The total time required to dump the water overboard from the propellant tanks will be monitored and recorded.

2.3.1.2.3.6 Test No. 6

Objective. The objective of this test is to determine the operating characteristics of the propellant system during normal system operation.

Instrumentation. Pressure-indicating instruments will be located at points 7, 8, 10, 14, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, and 47, as designated in paragraph 2.3.1.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. A pressure by-pass line will be installed parallel to the squib valve.

2. The propellant tanks will be filled with water.

3. The helium tank will be pressurized to 4500 psig with nitrogen.

4. The regulator outlet pressure should read 300 psig at static conditions.

5. With the exception of the engine solenoid valves, all propellant system solenoid valves will be open.

Test Program. Pulse mode performance characteristics of the system during single engine operation will be determined at a regulator inlet pressure of 4500 psig. Instrumentation will be provided to automatically actuate the fuel and oxidizer injector valves of an engine both individually and simultaneously in a firing sequence for periods of time ranging from 10 milliseconds to five seconds duration. The test will be performed on each of the six engines.

2.3.1.2.3.7 Test No. 7

Objective. The objective of this test is to determine the steady-state operating characteristics of the propellant system during simultaneous firing of three engines.

Instrumentation. Pressure-indicating instruments will be located at points 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 19, 20, 21, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, and 47, as designated in paragraph 2.3.1.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. A pressure by-pass line will be installed parallel to the squib valve.

2. The propellant tanks will be filled with water

3. The helium tank will be pressurized to 4500 psig with nitrogen.

4. The regulator outlet pressure should read 300 psig at static pressure.

5. With the exception of the engine solenoid valves, all propellant system solenoid valves will be open.

Test Program. System performance will be determined during the steady-state firing of three engines. This will be accomplished by actuating simultaneously the fuel and oxidizer injector valves of all combinations of three engines for a time period of ten seconds each.

2.3.1.2.3.8 Test No. 8

Objective. The objective of this test is to determine the water hammer effect on the propellant lines and the pressure surge effect on the helium lines.

Instrumentation. Pressure-indicating instruments will be located at points 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 19, 20, 21, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, and 47 as designated in paragraph 2.3.1.2.1 (Data Requirements).

System Requirements.

1. With the exception of the engine solenoid valves, all propellant system solenoid valves will be open.

2. An unfired squib valve will be installed into the system, and the pressure by-pass line parallel to the squib valve will be removed.

3. A burst disc will be installed into both the fuel and oxidizer lines.

4. A pressure no greater than 1 torr will be produced in the following lines:

    (a) Outlet of the burst disc housing to the inlet of each engine

    (b) Outlet of the squib valve to the inlet of the check valves

5. The propellant tanks will be filled with water.

6. The helium tank will be pressurized to 4500 psig with nitrogen.

Test Program. Water hammer effect on the propellant lines and pressure surge effect on the helium lines will be determined by energizing the helium squib valve and recording all pressures at the points designated. The oxidizer and fuel lines will be evacuated prior to the firing of the squib to more closely simulate high-altitude conditions.

2.3.1.2.3.9 Test No. 9

Objective. The objective of this test is to determine the system operating characteristics during simulated regulator failures.

Instrumentation. Pressure-indicating instruments will be located at points 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 19, 20, 21, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, and 47, as designated in paragraph 2.3.1.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. The propellant tanks will be filled with water.
2. The helium tank will be pressurized to 4500 psig with nitrogen.
3. The secondary regulator outlet pressure should read 300 psig at static conditions.
4. With the exception of the engine solenoid valves, all propellant system solenoid valves will be open.
5. The system will include appropriate lines and valves to permit various simulated failures.

Test Program. Regulator failure mode operating characteristics will be determined for single-, dual-, and three-engine operation by simulating individual failures of either the primary or secondary stages of the regulators. By operating valves that have been installed in the system to permit selective routing of the pressurizing gas, the primary or secondary stages of the regulators can be by-passed or blocked. Simultaneous actuation of the fuel and oxidizer injector valves for 10-second periods will be performed while simulating failed-open primary stages, failed-open secondary stages, and failed-closed regulators.

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2.3.1.2.3.10 Test No. 10

Objective. The objective of this test is to determine the system operating characteristics during simulated check valve failure.

Instrumentation. Pressure-indicating instruments will be located at points 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 19, 20, 21, 25, 27, 29, 31, 33, 37, 39, 41, 43, 45, and 47, as designated in paragraph 2.3.1.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. The propellant tanks will be filled with water.

2. The helium tank will be pressurized to 4500 psig with nitrogen.

3. The secondary regulator outlet pressure should read 300 psig at static conditions.

4. With the exception of the engine solenoid valves, all propellant solenoid valves will be open.

5. The system will include appropriate lines and valves to permit various simulated failures.

Test Program. Check valve failure mode operating characteristics will be determined for single-, dual-, and three-engine operation by simulating individual failure of each bank of check valves. By operating valves that have been installed in the system to permit selective routing of the pressurizing gas, each bank of check valves can be by-passed or blocked.

2.3.1.2.3.11 Test No. 11

Objective. The objective of this test is to determine the operating characteristics of the propellant system during a normal entry propellant dump operation.

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[redacted]

Instrumentation. Pressure-indicating instruments will be located at points 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 19, 20, 21, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, and 47, as designated in paragraph 2. 3. 1. 2. 1 (Data Requirements).

System Requirements.

1. A pressure by-pass line will be installed parallel to the squib valve.

2. The propellant tanks will be filled with water.

3. The helium tank will be pressurized to 4500 psig with nitrogen.

4. The regulator outlet pressure should read 300 psig at static pressure.

5. With the exception of the engine solenoid valves, all propellant system solenoid valves will be open.

Test Program. Normal entry dump operation will be determined by testing the ability of the system and the time required to dump the remaining propellant. The test will be conducted with 50 percent of the propellant remaining in the tanks.

2.3.1.2.3.12 Test No. 12

Objective. The objective of this test is to determine the operating characteristics of the propellant system during a pad abort dump operation.

Instrumentation. Pressure-indicating instruments will be located at points 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 19, 20, 21, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, and 47, as designated in paragraph 2.3.1.2.1 (Data Requirements).

System Requirements.

1. With the exception of the engine solenoid valves, all propellant system solenoid valves will be open.

[redacted]

2. An unfired squib valve will be installed in the system and the pressure by-pass line parallel to the squib valve will be removed.

3. A burst disc will be installed in the fuel and oxidizer lines.

4. The propellant tanks will be pressurized to 4500 psig with nitrogen.

Test Program. The ability of the system to function properly during a simulated pad abort maneuver will be determined by energizing the helium squib valve, the oxidizer overboard dump squib valve, and the propellant tank by-pass squib valves in accordance with a programmed sequence that will include firing five engines simultaneously.

2.3.1.2.3.13 Test No. 13

Objective. The objective of this test is to determine the steady-state operating characteristics of the propellant system during the simultaneous firing of two engines.

Instrumentation. Pressure-indicating instruments will be located at points 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 19, 20, 21, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, and 47, as designated in paragraph 2.3.1.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. A pressure by-pass line will be installed parallel to the squib valve.

2. The propellant tanks will be filled with water.

3. The helium tank will be pressurized to 4500 psig with nitrogen.

4. The regulator outlet pressure should read 300 psig at static pressure.

5. With the exception of the engine solenoid valves, all propellant system solenoid valves will be open.

Test Program. System performance will be determined during the steady-state firing of two engines. This will be accomplished by actuating simultaneously the fuel and oxidizer injector valves of all combinations of two engines for a time period of ten seconds each.

2.3.1.2.3.14 Test No. 14

Objective. The objective of this test is to determine the operating characteristics of the propellant system during single firing of each engine at the various pulse rates.

Instrumentation. Pressure-indicating instruments will be located at points 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 19, 20, 21, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, and 47, as designated in paragraph 2.3.1.2.1 (Data Requirements).

System Requirements.

1. A pressure by-pass line will be installed parallel to the squib valve.

2. The propellant tanks will be filled with water.

3. The helium tank will be pressurized to 4500 psig with nitrogen.

4. The regulator outlet pressure should read 300 psig at static pressure.

5. With the exception of the engine solenoid valves, all propellant system solenoid valves will be open.

Test Program. Pulse mode performance characteristics of the system during single engine operating will be determined at a regulator inlet pressure of 4500 psig. Instrumentation will be provided to automatically actuate the fuel and oxidizer injector valves of an engine in a firing sequence for periods of time ranging from 10 milliseconds to 5 seconds duration. The test will be performed on each of the six engines.

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2.3.1.2.3.15 Test No. 15

Objective. The objective of this test is to determine the steady-state operating characteristics of the propellant system during single firing of each engine.

Instrumentation. Pressure-indicating instruments will be located at points 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 19, 20, 21, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, and 47, as designated in paragraph 2.3.1.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. A pressure by-pass line will be installed parallel to the squib valve.

2. The propellant tanks will be filled with water.

3. The helium tank will be pressurized to 4500 psig with nitrogen.

4. The regulator outlet pressure should read 300 psig at static pressure.

5. With the exception of the engine solenoid valves, all propellant system solenoid valves will be open.

Test Program. Steady-state single-engine system performance will be determined at a regulator inlet pressure of 4500 psig by actuating the fuel and oxidizer injector valves simultaneously for periods of 30 seconds. The test will be performed on each of the six engines.

2.3.1.2.4 Phase II Procedure. The first series of tests will be performed with distilled water and nitrogen as the fluid media. The purpose of the water tests is four-fold: (1) to provide information to be used in the propellant testing phase, (2) to shakedown the system and instrumentation, (3) to familiarize personnel with the propellant system, and (4) to establish propellant handling techniques. The tests will include propellant tank calibrations, bladder expulsion efficiency tests, and a system functional test. Prior to the functional test, the setup will be checked to verify conformance with the system schematic, tightness of tubing connections, continuity of

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electrical systems, and adequacy of support for all components and lines. The propellant tanks will then be filled with distilled water and the helium tank pressurized initially to 500 psig. After the leakproof integrity of the system has been verified, the helium tank will be pressurized to 4500 psig, and the functional test will be performed.

The second series of tests will be performed with the storable propellants and will be divided into two categories: (1) propellant familiarization tests and (2) engine firing tests. Included in the familiarization tests will be propellant tank filling and draining techniques, system purging techniques, and individual fuel and oxidizer flow tests through the rocket engines. When performing the engine hot-firing tests, the test setup will be examined for adequacy of heat shielding for all instrumentation in addition to the established pretest system checks. The propellant tanks will then be filled with the storable propellants in accordance with detailed procedures developed and verified during the familiarization testing period. The helium tank will be pressurized initially to 500 psig, and after the leakproof integrity of the system has been verified, it will be pressurized to 4500 psig. Initial pressure and temperature readings will be recorded and the recording instruments started. This procedure will be followed for all the engine firing tests that will include single and multiple engine steady-state operation, single and multiple engine pulsing operation, simulated mission sequences, and component malfunction tests. After each testing period, the recorded data and test setup will be examined for inconsistencies, the tanks and lines will be emptied of propellants, and the systems will be cleaned and purged.

Upon satisfactory completion of the first two series of tests, the Phase II program may be augmented by a series of trouble-shooting tests, integrated systems tests, and other special tests, as required. The integrated systems include the RCS and those portions of the guidance and control system that supply the programmed signals for the controlled firing of the rockets, both automatically and manually. Simulated signals from the guidance and control system will be used where feasible.

2.3.1.2.5 Phase III Procedure. The test procedures for Phase III will be the same as those for Phase II, except for the incorporation of improved testing techniques developed during Phase II.

2.3.1.3 Equipment

The equipment required to accomplish the objectives of the breadboard test program will include a test stand; pressure, temperature, and flow sensing elements; indicating and recording equipment; and miscellaneous support equipment.

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The test stand will be a full-scale sheet metal mock-up of the RCS compartments. The internal configuration of the compartments will be identical to the command module with the exception of the materials of construction. The outer configuration of the command module in the area of the rocket engines will be duplicated as accurately as possible to provide realistic nozzle exit conditions. The test stand will be updated throughout the test program.

A general list of the types of sensing elements, recording equipment, and miscellaneous equipment required for the test program follows:

1. Oscillograph (direct write, 18-channel, electronic flash timing)
2. Amplifiers (wide-band, dc with attenuators)
3. Temperature recorder (1/2 sec full-scale response; chart speed 6, 12, 24, and 30 in. per sec)
4. Oscillators, battery powered
5. Pulse rate convertor
6. Calibrated and sensitivity thermocouple, 12-channel unit
7. Thermocouple reference junction (rack mount, rear input and output)
8. Signal conditions module racks
9. Cabinets (plates, shelves, strips, panels, doors, frames, side panels)
10. X-Y plotter, dual pen
11. Pressure regulators (0 to 5000 psig)
12. Accumulators
13. Pressure regulators (0 to 3600 psig)
14. Galvanometers
15. Pressure transducers (0 to 500 psig)
16. Pressure transducers (0 to 5000 psig)

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17. Signal conditioning module, power supply

18. Flow strain gage (liquid, 0 to 10 gpm, 1 percent linearity, output voltage 4 millivolts per volt

19. Thermocouple pick-ups

20. Check valves

21. Ball valves

22. Filters

23. Pressure gages

24. Solenoid valves

25. Switch, crossbar

26. Connectors (hold, terminal plug)

27. Cards (transducer bridge, circuit structure)

28. Cards (galvanometer drive, circuit structure)

29. Wire (6 conductor, shielded, 22 gage, texlon inpregnated)

30. Connector, (wall receptacle, 7 pin)

31. Personnel protective clothing with accessories, such as airpacks, breathing canisters, face shields, gloves, boots, aprons, etc.

32. Special personnel protective equipment, such as air sampling analyzer, hydrazine analyzer, N_2O_4 analyzer, and a MMH analyzer.

33. Decontamination equipment including vapor degreaser, black light analyzer, storage bag sealing kit, etc.

2.3.1.4 Facilities

A special test facility for the breadboard test program will be constructed at the S&ID facility in Downey, California. No attempt will be made to simulate altitude in these tests. The facility design and its operation will comply with all sections and paragraphs of Air Force technical manual T.O. 11C-1-6(1). The important design and operation details include explosion hazard control, toxicity hazard control, ventilation scrubber system, fuel and oxidizer scrubber systems, test personnel protection, toxic detectors, visual and audible warning system, meteorological instruments, control room ventilation system, and safety showers and eyewash basins.

2.3.1.5 Test Schedule

The test schedule for breadboard testing of the command module RCS is shown in Figure 2-4.

2.3.2 Breadboard Testing of the Apollo Service Module RCS

2.3.2.1 Objectives

The breadboard testing of the service module RCS (see Figure 2-5) will accomplish the following objectives.

1. Provide experimental evaluation of the integrated system

2. Prove design concepts

3. Resolve design difficulties

4. Ensure compatibility of components

5. Provide data for system calibration

6. Resolve propellant handling techniques

7. Verify the suitability of the system for ultimate use

2.3.2.2 Test Plan

The testing of the breadboard system will be divided into three progressive phases: Phase I, Phase II, and Phase III. The major differences among the test phases will be the types of components used in the test setups and the fluid media used during the test runs. Phase I testing will employ available off-the-shelf components that will fulfill the preliminary design requirements. The fluid media to be used during Phase I will be water and nitrogen.

Phase II components will be flight articles which satisfy the requirements of North American equipment specifications but which have not completed qualification testing. Phase III components will be fully qualified articles. The fluid media to be used during Phase II and Phase III testing will initially be distilled water and will ultimately be the hypergolic propellants.

[redacted]

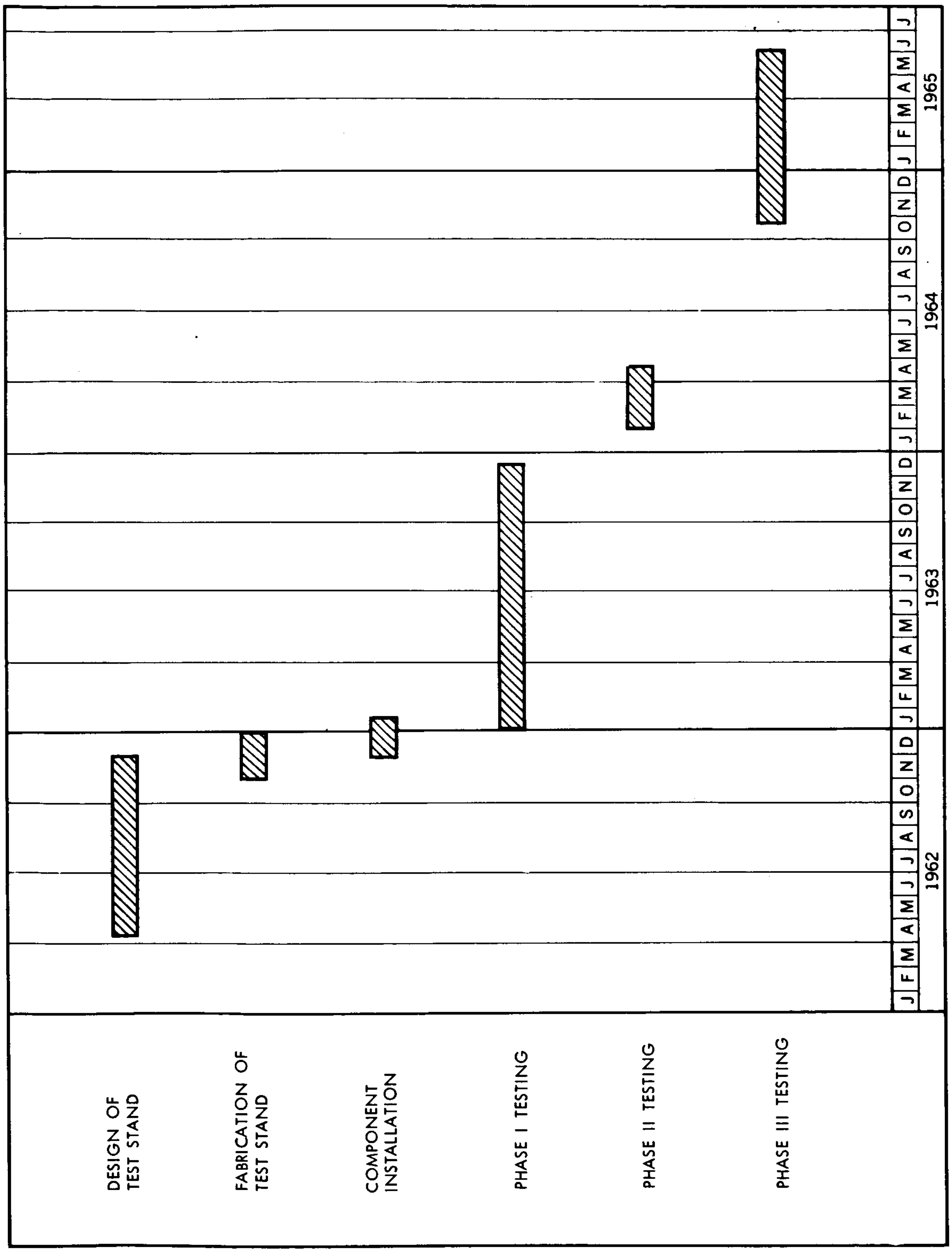

Figure 2-4. S&ID Schedule of Command Module Reaction Control System Breadboard Tests

[redacted]

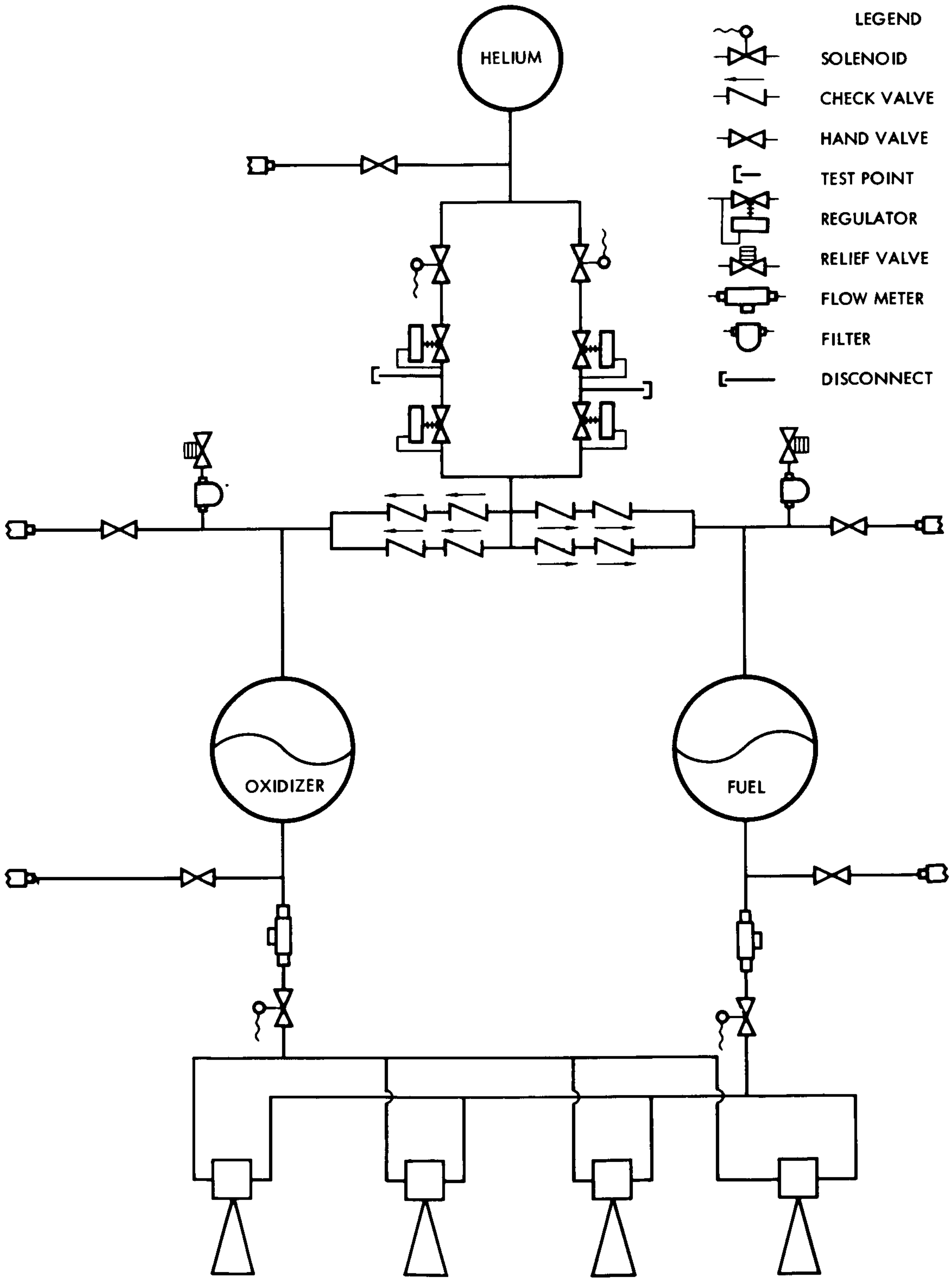

Figure 2-5. Service Module Reaction Control Propellant Feed Subsystem Flow Diagram

[redacted]

2.3.2.2.1 Data Requirements. During the testing of the service module RCS, the following listed items will be monitored and recorded:

1. Pressure of gas in helium tank
2. Temperature of gas in helium tank
3. Outlet pressure of primary stage of regulator No. 1
4. Outlet pressure of primary stage of regulator No. 2
5. Outlet pressure of secondary stage of regulator No. 1
6. Outlet pressure of secondary stage of regulator No. 2
7. Inlet pressure of check valve assembly
8. Pressure of gas in fuel tank on gas side of bladder
9. Temperature of gas in fuel tank on gas side of bladder
10. Pressure of fuel in fuel tank on fuel side of bladder
11. Temperature of fuel in fuel tank on fuel side of bladder
12. Pressure of gas in oxidizer tank on gas side of bladder
13. Temperature of gas in oxidizer tank on gas side of bladder
14. Pressure of oxidizer in oxidizer tank on oxidizer side of bladder
15. Temperature of oxidizer in oxidizer tank on oxidizer side of bladder
16. Outlet pressure of fuel solenoid valve
17. Outlet pressure of oxidizer solenoid valve
18. Flow rate of fuel
19. Flow rate of oxidizer
20. Pressure in fuel line of -Y engine
21. Temperature in fuel line of -Y engine

[redacted]

[redacted]

22. Pressure in oxidizer line of -Y engine
23. Temperature in oxidizer line of -Y engine
24. Pressure in fuel line of -R engine
25. Temperature in fuel line of -R engine
26. Pressure in oxidizer line of -R engine
27. Temperature in oxidizer line of -R engine
28. Pressure in fuel line of +Y engine
29. Temperature in fuel line of +Y engine
30. Pressure in oxidizer line of +Y engine
31. Temperature in oxidizer line of +Y engine
32. Pressure in fuel line of +R engine
33. Temperature in fuel line of +R engine
34. Pressure in oxidizer line of +R engine
35. Temperature in oxidizer line of +R engine
36. Pressure in engine chamber of -Y engine
37. Pressure in engine chamber of -R engine
38. Pressure in engine chamber of +Y engine
39. Pressure in engine chamber of +R engine

2.3.2.2.2 Test Procedures. The service module reaction control system consists of four similar, independent systems. For breadboard test purposes, only two systems will be used, and these will be identified as system A and system B. Off-the-shelf components will be installed on system A for Phase I testing. Components that meet S&ID specifications, but have not been qualified, will be installed on system B for Phase II testing. During Phase II testing, system A will be reworked to incorporate qualified components for Phase III testing. At the conclusion of Phase II testing, system B will be reworked to incorporate qualified components for Phase III testing. The two systems will be tested during Phase III.

[redacted]

The tests will be performed at existing ambient conditions of pressure and temperature with no attempt to simulate flight environments. Safety requirements will be strictly adhered to at all times, especially when nitrogen tetroxide and hydrazine/unsymmetrical-dimethylhydrazine are being handled, because the propellants are not only hypergolic by nature, but highly toxic as well. Individual system components will be tested for proof pressure, leakage, and compatibility with the applicable fluid medium before installation in the breadboard system.

2.3.2.2.3 Phase I - Procedure. The service module reaction control system will be free from contaminates at all times. All components, tubing, and fittings will be purged and decontaminated prior to assembly as a system. The cleaning process to be used on all the components, tubing, and fittings will consist of (1) purge with high flow, dry, filtered nitrogen, (2) flush with trichloroethylene, and (3) purge again with high-flow, dry, filtered nitrogen. All components, tubing, and fittings will be capped immediately after cleaning and will remain capped until installation into the system. All system access ports and instrumentation ports will either be capped or connected at all times to prevent contamination of the system.

The following is a list of the pretest conditions to be verified prior to the start of all tests.

1. Conformance of the system to the test schematic
2. Tightness of all mechanical fluid connections
3. Proper installation of electrical wiring
4. Adequate support of all components
5. Correct installation of instrumentation
6. Leakproof integrity of system

The system test media will be as follows:

1. Nitrogen gas—oil free per Specification MIL-N-6011 Grade A, Type I
2. Distilled water having a minimum specific resistivity of 50,000 ohms

[redacted]

[redacted]

The fluid filling lines will consist of clean plumbing and will contain a filter immediately upstream of the test system. The filter will be capable of removing all particles that are larger than 60 microns in size.

At the end of the working day, the system will be depressurized and cleaned. The nitrogen supply system upstream and downstream of the check valves will be depressurized carefully. The propellant tanks and lines will be emptied of water. The system will then be purged and dried with high-flow, dry, filtered nitrogen.

Phase I testing will be divided into two series of tests. Low response instrumentation will be used during the first series of tests; high response instrumentation and permanent recording equipment will be used during the second series of tests. Because of the use of low-response instrumentation, the first series of tests will be performed primarily to gain preliminary knowledge of the breadboard system and testing techniques.

Because water will be used in place of the propellants and nitrogen will be used in place of helium during Phase I testing, system temperatures will not be monitored. The system pressures to be measured during the individual tests are designated in the following detailed descriptions of the tests.

2.3.2.2.3.1 Test No. 1

Objective. The objective of this test is to determine whether a high differential pressure will cause extrusion of the oxidizer and fuel bladders into the small holes of the tank outlets.

Test Program. After installation of the bladder specimen in a test fixture, pressure differentials of 50 to 550 psi will be applied across the specimen for varying time periods. The specimen will be examined after each pressure test.

2.3.2.2.3.2 Test No. 2

Objective. The objectives of this test are to determine the maximum amount of water that can be loaded into each of the propellant tanks and to determine the expulsion efficiency of the bladders.

Instrumentation. Pressure gages will be used to indicate system pressures. The water supply tank will be calibrated to indicate the quantity of water contained within the tank.

[redacted]

Test Program. The volumes of the oxidizer tank and the fuel tank will be determined by filling the tanks individually with a known quantity of water from the calibrated supply tank. The expulsion efficiency of the bladders can be established by forcing the water from the system tanks into the calibrated supply tank and observing the quantity of water expelled.

2.3.2.2.3.3 Test No. 3

Objective. The objective of this test is to verify that the propellant system and the rocket engines function properly.

Instrumentation. Pressure-indicating instruments will be located at points 1, 5, 6, 8, 12, 20, 22, 24, 26, 28, 30, 32, and 34, as designated in paragraph 2.3.2.2.1 (Data Requirements).

System Requirements.

1. The propellant tanks will be filled with water.

2. The helium tank will be pressurized to 750 psig with nitrogen.

3. The regulator outlet pressure should read 190 psig at static conditions.

4. All propellant system solenoid valves will be open.

Test Program. A single-engine system functional test will be performed by individually actuating the fuel and oxidizer injector valves for five seconds, followed by simultaneous actuation of both fuel and oxidizer injector valves for another five seconds. The test will be performed on each of the four engines.

2.3.2.2.3.4 Test No. 4

Objective. The objective of this test is to determine the size of a flow restrictor that must be installed on the engines to produce the required 90 psia engine chamber pressure.

[redacted]

Instrumentation. Pressure-indicating instruments will be located at the inlet and/or outlet of the flow-measuring instruments and at points 1, 5, 6, 8, 10, 12, 14, 20, 22, 24, 26, 28, 30, 32, 34, 36, 37, 38, and 39, as designated in paragraph 2.3.2.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. An orifice plate adapter and an orifice plate will be installed on each of the four engines.

2. The propellant tanks will be filled with water.

3. The helium tank will be pressurized to 2100 psig with nitrogen.

4. The regulator outlet pressure should read 190 psig at static conditions.

5. All propellant system solenoid valves will be open.

Test Program. The 90 psia chamber pressure generated during engine firing will be duplicated by means of the flow restricting orifice attached to each engine; the chamber pressure will be determined by the flow of water through the system at normal propellant flow rates. The fuel and oxidizer injector valves of individual engines will be actuated simultaneously until the engine chamber pressure is constant.

2.3.2.2.3.5 Test No. 5

Objective. The objective of this test is to determine the flow rate of water through the rocket engine injector valves.

Instrumentation. Pressure-indicating instruments will be located at the inlet and/or outlet of the flow-measuring instruments and at points 1, 5, 6, 8, 10, 12, 14, 20, 22, 24, 26, 28, 30, 32, 34, 36, 37, 38, and 39, as designated in paragraph 2.3.2.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

[redacted]

System Requirements.

1. The propellant tanks will be filled with water.

2. The helium tank will be pressurized to 2100 psig with nitrogen.

3. The regulator outlet pressure should read 190 psig at static conditions.

4. All propellant system solenoid valves will be open.

Test Program. Flow rates through the engine injector valves will be determined by individual actuation of the fuel and oxidizer valves for 15-second periods, followed by simultaneous actuation of both valves for another 15 seconds. The test will be performed on each of the four engines.

2.3.2.2.3.6 Test No. 6

Objective. The objective of this test is to determine the operating characteristics of the propellant system during normal system operation.

Instrumentation. Pressure-indicating instruments will be located at the inlet and/or outlet of the flow-measuring instruments and at points 1, 5, 6, 8, 10, 12, 14, 20, 22, 24, 26, 28, 30, 32, 34, 36, 37, 38, and 39, as designated in paragraph 2.3.2.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. The propellant tanks will be filled with water.

2. The helium tank will be pressurized with nitrogen as follows:

   Test No. 6A, 2100 psig

   Test No. 6B, 4500 psig

[redacted]

[redacted]

3. The regulator outlet pressure should read 190 psig at static conditions.

4. All propellant system solenoid valves will be open.

Test Program. Single engine system performance and flow rates through the engine injector valves will be determined during steady-state flow for periods up to one minute. After actuating the fuel and oxidizer injector valves individually for 10 seconds each, the valves will be actuated simultaneously for periods of 30 seconds and then 60 seconds. The test will be performed on each of the four engines.

2.3.2.2.3.7 Test No. 7

Objective. The objective of this test is to determine the system operating characteristics during simulated regulator failures.

Instrumentation. Pressure-indicating instruments will be located at the inlet and/or outlet of the flow-measuring instruments and at points 1, 3, 4, 5, 6, 8, 10, 12, 14, 20, 22, 24, 26, 28, 30, 32, 34, 36, 37, 38, and 39, as designated in paragraph 2.3.2.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. The system will include appropriate lines and valves to permit the following simulated failures.

   a. Primary stage of regulator No. 1 failed open.

   b. Primary stage of regulator No. 2 failed open.

   c. Secondary stage of regulator No. 1 failed open.

   d. Secondary stage of regulator No. 2 failed open.

   e. Regulator No. 1 failed closed.

   f. Regulator No. 2 failed closed.

[redacted]IAL

2. The propellant tanks will be filled with water.

3. The helium tank will be pressurized to 4500 psig with nitrogen.

4. The secondary regulator outlet pressure should read 190 psig at static conditions.

5. All propellant system solenoid valves will be open.

Test Program. Regulator failure mode operating characteristics will be determined for single- and dual-engine operation by simulating individual failures of either the primary or secondary stages of the regulators. By operating valves that have been installed in the system to permit selective routing of the pressurizing gas, the primary or secondary stages of the regulators can be by-passed or blocked. Simultaneous fuel and oxidizer injector valve actuation for 10-second periods will be performed while simulating failed-open primary stages, failed-open secondary stages, and failed-closed regulators.

2.3.2.2.3.8 Test No. 8

Objective. The objective of this test is to determine the system operating characteristics during simulated check valve failures.

Instrumentation. Pressure-indicating instruments will be located at the inlet and/or outlet of the flow measuring instruments and at points, 1, 5, 6, 7, 8, 10, 12, 14, 20, 22, 24, 26, 28, 30, 32, 34, 36, 37, 38, and 39, as designated in paragraph 2.3.2.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. The system will include appropriate lines, valves, or other hardware to simulate one failed-closed check valve in each of the four branches of the check valve assembly.

2. The propellant tanks will be filled with water.

[redacted]

3. The helium tank will be pressurized to 4500 psig with nitrogen.

4. The secondary regulator outlet pressure should read 190 psig at static conditions.

5. All propellant system solenoid valves will be open.

Test Program. Check valve failure mode operating characteristics will be determined for single- and dual-engine operation by simulating a failed-closed check valve in the check valve assembly. By blocking one of the four branches of the assembly, a failed-closed condition can be duplicated. Simultaneous fuel and oxidizer injector valve actuation for 10 second periods will be performed for a check valve failure in each of the four branches of the assembly.

2.3.2.2.3.9 Test No. 9

Objective. The objective of this test is to determine the steady-state operating characteristics of the propellant system during dual-engine operation.

Instrumentation. Pressure-indicating instruments will be located at the inlet and/or outlet of the flow-measuring instruments and at points 1, 5, 6, 8, 10, 12, 14, 20, 22, 24, 26, 28, 30, 32, 34, 36, 37, 38, and 39, as designated in paragraph 2.3.2.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. The propellant tanks will be filled with water.

2. The helium tank will be pressurized to 4500 psig with nitrogen.

3. The secondary regulator outlet pressure should read 190 psig at static conditions.

4. All propellant system solenoid valves will be open.

[redacted]

[redacted]

Test Program. Steady-state dual-engine system performance will be determined by simultaneous actuation of the injector valves of two adjacent engines. The period of actuation will be for 30 seconds and will be performed on each of the four combinations of adjacent engines.

2.3.2.2.3.10 Test No. 10

Objective. The objective of this test is to determine the steady-state operating characteristics of the propellant system during single-engine operation.

Instrumentation. Pressure-indicating instruments will be located at the inlet and/or outlet of the flow-measuring instruments and at points 1, 5, 6, 8, 10, 12, 14, 20, 22, 24, 26, 28, 30, 32, 34, 36, 37, 38, and 39, as designated in paragraph 2.3.2.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. The propellant tanks will be filled with water.

2. The helium tank will be pressurized to 4500 psig with nitrogen.

3. The secondary regulator outlet pressure should read 190 psig at static conditions.

4. All propellant system solenoid valves will be open.

Test Program. Steady-state single-engine system performance will be determined by actuating the fuel and oxidizer injector valves simultaneously for periods of 30 seconds. The test will be performed on each of the four engines.

2.3.2.2.3.11 Test No. 11

Objective. The objective of this test is to determine the pulse mode operating characteristics of the propellant system during single-engine operation.

[redacted]

[redacted]

Instrumentation. Pressure-indicating instruments will be located at the inlet and/or outlet of the flow-measuring instruments and at points 1, 5, 6, 8, 10, 12, 14, 20, 22, 24, 26, 28, 30, 32, 34, 36, 37, 38, and 39, as designated in paragraph 2.3.2.2.1 (Data Requirements). Instruments for measuring flow will be located in both the oxidizer and fuel feed lines.

System Requirements.

1. The propellant tanks will be filled with water.

2. The helium tank will be pressurized to 4500 psig with nitrogen.

3. The secondary regulator outlet pressure should read 190 psig at static conditions.

4. All propellant system solenoid valves will be open.

Test Program. Pulse mode performance characteristics of the system will be determined during single-engine operation. Instrumentation will be provided to automatically actuate the fuel and oxidizer injector valves of an engine both individually and simultaneously in a firing sequence for periods of time ranging from 10 milliseconds to 5 seconds duration. The test will be performed on each of the four engines.

2.3.2.2.4 Phase II Procedure. The first series of tests will be performed with distilled water and nitrogen as the fluid media. The purpose of the water tests is four-fold: (1) to provide information to be used in the propellant testing phase, (2) to shakedown the system and instrumentation, (3) to familiarize personnel with the propellant system, and (4) to establish propellant handling techniques. The tests will include propellant tank calibrations, bladder expulsion efficiency tests, and a system functional test. Prior to the functional test, the setup will be checked to verify conformance with the system schematic, tightness of tubing connections, continuity of electrical systems, and adequacy of support for all components and lines. The propellant tanks will then be filled with distilled water and the helium tank pressurized initially to 500 psig. After the leakproof integrity of the system has been verified, the helium tank will be pressurized to 4500 psig, and the functional test will be performed.

The second series of tests will be performed with the storable propellants and will be divided into two categories: (1) propellant

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familiarization tests and (2) engine firing tests. Included in the familiarization tests will be propellant tank filling and draining techniques, system purging techniques, and individual fuel or oxidizer flow tests through the rocket engines. When performing the engine hot-firing tests, the test setup will be examined for adequacy of heat shielding for all instrumentation in addition to the established pretest system checks. The propellant tanks will then be filled with the storable propellants in accordance with detailed procedures developed and verified during the familiarization testing period. The helium tank will be pressurized initially to 500 psig, and after the leakproof integrity of the system has been verified, it will be pressurized to 4500 psig. Initial pressure and temperature readings will be recorded and the recording instruments started. This procedure will be followed for all the engine firing tests that will include single- and dual-engine steady-state operation, single- and dual-engine pulsing operation, simulated mission sequences and component malfunction tests. After each testing period, the recorded data and test setup will be examined for inconsistencies, the tanks and lines will be emptied of propellants, and the systems will be cleaned and purged.

Upon satisfactory completion of the first two series of tests, the Phase II program may be augmented by a series of trouble-shooting tests, integrated systems tests, and other special tests, as required. The integrated systems include the RCS and those portions of the guidance and control system that supply the programmed signals for the controlled firing of the rockets, both automatically and manually. Simulated signals from the guidance and control system will be used where feasible.

2.3.2.2.5 Phase III Procedure. The test procedures for Phase III will be similar to those for Phase II except for the incorporation of improved testing techniques developed during Phase II.

2.3.2.3 Equipment

The equipment required to accomplish the objectives of the breadboard test program will include a test stand; pressure, temperature, and flow sensing elements; indicating and recording equipment and miscellaneous support equipment.

The test stand will be a tubular steel framework to which is attached a full-scale metal mock-up of a service module RCS package. The RCS package will support the helium and propellant tanks, the numerous components that make up the pressurization and propellant distribution subsystems, and the cluster of four rocket engines.

The sensing elements, recording equipment, and miscellaneous equipment required for the test program are essentially the same as those

[redacted]

items listed in the breadboard tests of the reaction control for the command module. (See paragraph 2.3.1.3.)

2.3.2.4 Facilities

Facilities required for the breadboard testing of the service module RCS are essentially the same as those listed in the command module reaction control breadboard tests. (See paragraph 2.3.1.4.)

2.3.2.5 Test Schedule

The test schedule for the service module RCS is shown in Figure 2-6.

2.3.3 Testing of Propellant Flow into Evacuated Lines

2.3.3.1 Objectives

This test will determine the existence and possible solution of potential freezing problems resulting from the introduction of propellant into evacuated lines at temperatures and pressures existing in the command module RCS prior to entry.

The tests encompass two phases:

1. Phase I testing will use water as the test fluid and will determine the significant effects of (1) test fluid temperature, (2) pressure of the evacuated system, and (3) system volume.

2. The analysis of Phase II testing will determine the possibility of propellant freezing. This phase is an abbreviated schedule of tests conducted under conditions more severe than those actually existing. Since the N_2O_4 propellant is most likely to freeze, it will be tested prior to MMH, which freezes at 12 F. No further testing will be done if the N_2O_4 does not freeze and the results of Phase I testing do not indicate any unexpected effects as the different system parameters are varied. If the tests indicate the possibility that freezing will occur, the test program will be expanded to include testing of MMH under extreme conditions. If the results of Phase II testing, using either propellant, indicate possible freezing, the results of Phase I testing will be used to determine possible solutions to the freezing problem. After an analysis of Phase I, further tests will be conducted; the extent of these additional tests will be dictated by the results of Phase I. The data from the additional testing will also be analyzed.

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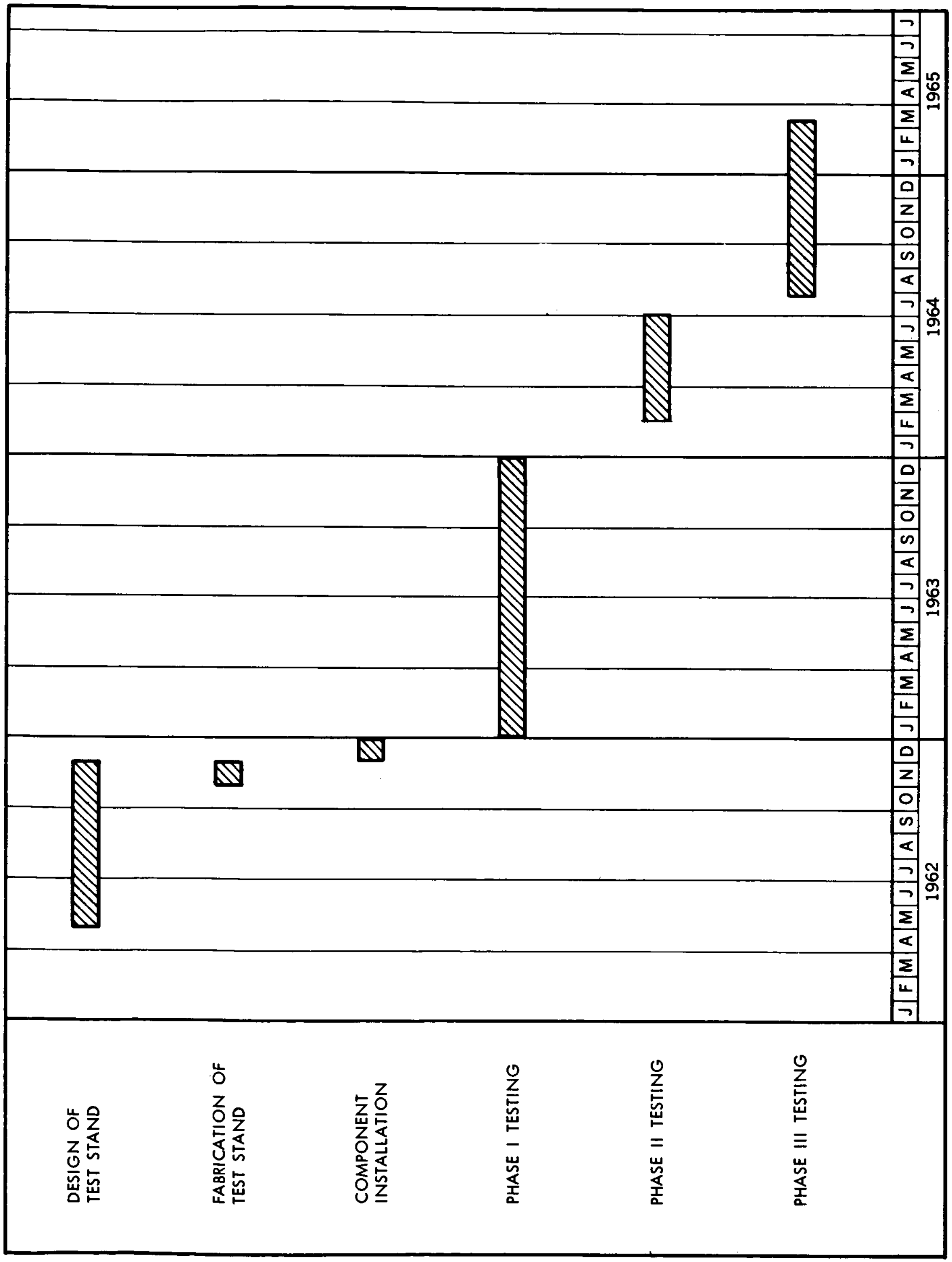

Figure 2-6. S&ID Schedule of Service Module Reaction Control System Breadboard Tests

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2.3.3.2 Test Plan

Phase I and Phase II testing are conducted at the following conditions:

Test Number	Evacuated System Pressure (psia)	Test Fluid Temperature (deg F)	Accumulator Volume (liters)	Storage Tank Pressure (psia)
Phase I - Test Fluid is Water				
I-1	0.005	40±2	12	20
I-2	0.010	40±2	12	20
I-3	0.020	40±2	12	20
I-4	0.005	60±2	12	20
I-5	0.005	80±2	12	20
I-6	0.005	40±2	12	20
Phase II - Test Fluid is N_2O_4				
II-1	0.005	40±2	12	20
II-2	0.005	40±2	12	20
Phase II* - Test Fluid is MMH				
II-3	0.005	40±2	12	20
II-4	0.005	40±2	12	20

*These tests to be conducted only if results of tests with N_2O_4 reveal possible freezing.

2.3.3.3 Equipment

A breadboard system, shown in Figure 2-7, is required for the tests. The tests will be conducted as follows:

1. The propellant storage tank will be filled with enough propellant to fill the system downstream.

2. The propellant tank then will be pressurized using gaseous nitrogen. The solenoid valve, SV_1, will be closed during this operation.

3. The propellant line will be evacuated through valve V_1, then this valve will be closed.

[redacted]

4. The propellant will be brought to the desired temperature.

5. When the desired test conditions are achieved, the solenoid valve, SV_1, will be opened to allow the propellant to flow into the line and the accumulator. The resultant temperatures and pressures will be recorded.

2.3.3.4 Facilities

The tests will be accomplished at the S&ID, Downey, laboratory, subject to safety restrictions in effect at the time of the tests.

2.3.3.5 Test Schedule

Figure 2-8 shows the proposed test schedule.

Test Phases I and II have been completed with no indication of propellant freezing observed; consequently, Phase III will not be conducted.

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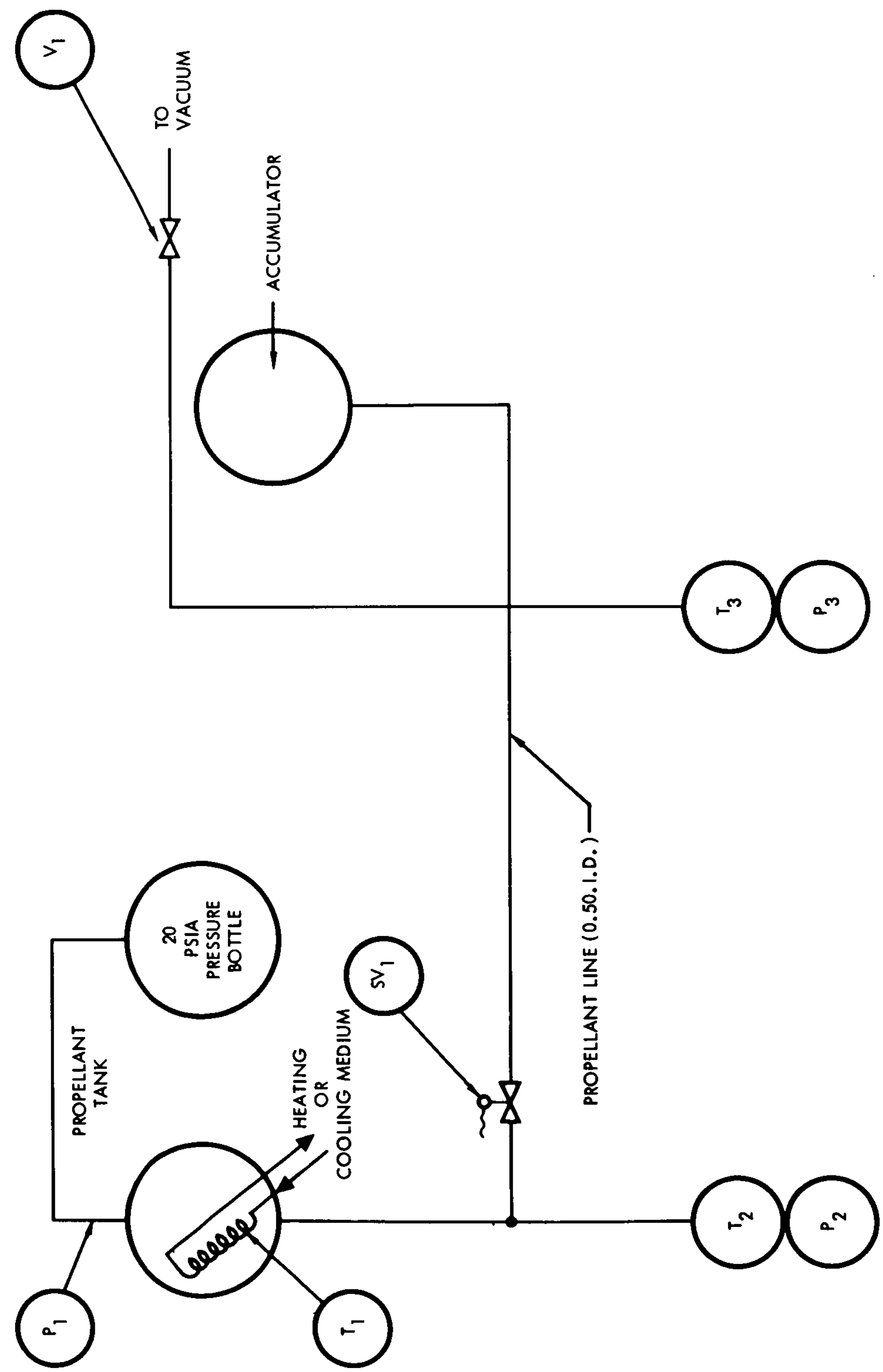

Figure 2-7. Command Module Propellant Flow Test Diagram

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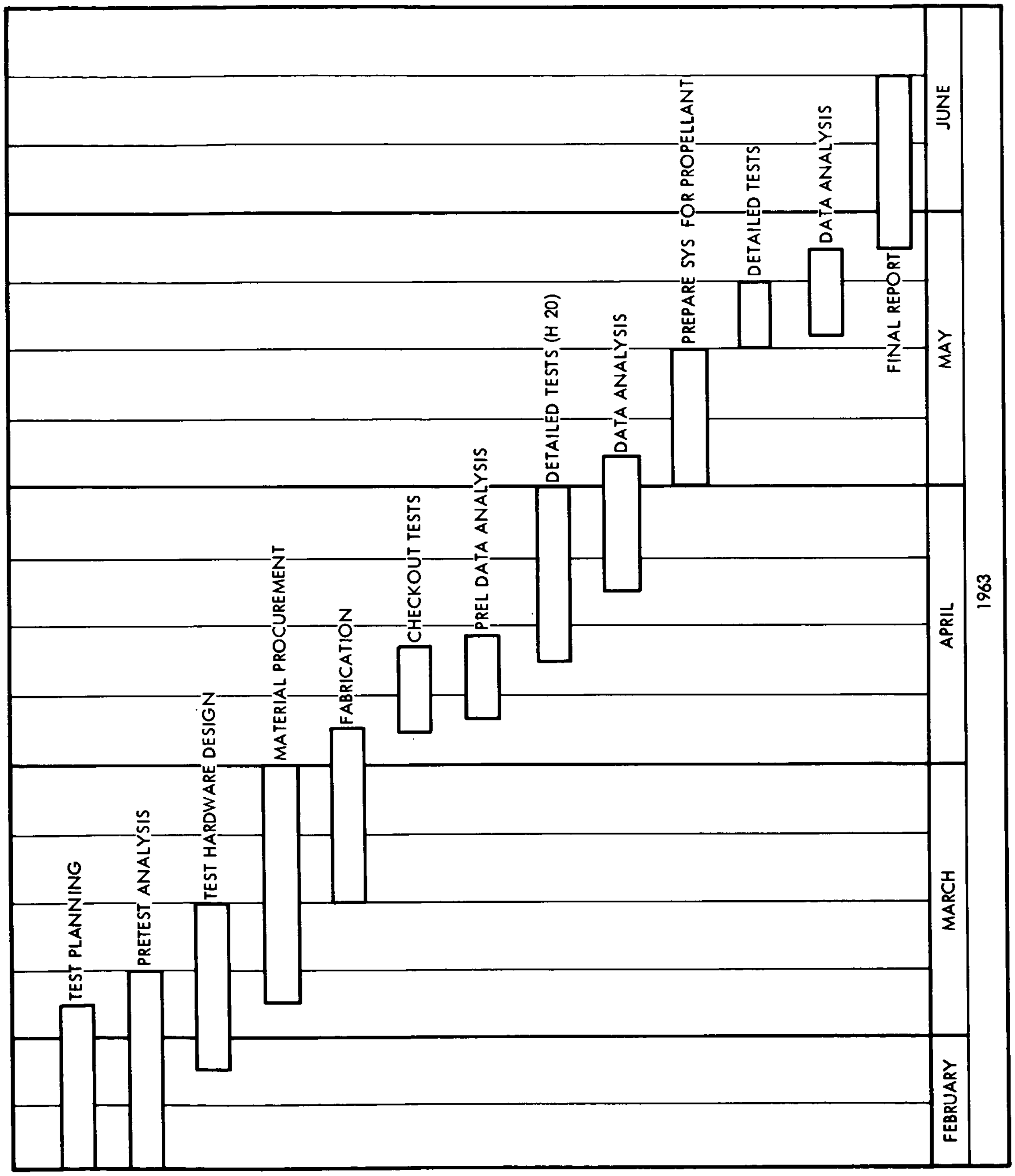

Figure 2-8. S&ID Schedule Command Module Propellant Flow Tests

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3.0 LAUNCH ESCAPE SYSTEM*

3.1 SCOPE

During the launch escape system development program, the rocket motor igniters will be tested. The launch escape, pitch control, and tower jettison motors will be statically fired to evaluate motor and solid propellant characteristics. Two simulated altitude performance tests will be conducted during the tower jettison motor development program to verify the adequacy of the motor design for Apollo flight testing. Flight test evaluation will be accomplished by means of pad abort and Little Joe II abort tests.

3.2 SUBCONTRACTOR TEST PLAN

3.2.1 <u>Launch Escape Rocket Motor Tests (Lockheed Propulsion Company)</u>

3.2.1.1 Objective

Completion of the launch escape motor development test program will assure the optimum configuration of motor components. The development tests will yield data on igniter and motor performance necessary for proper design evaluation of all motor components. Development testing will also produce a unit of finalized design worthy of entering a qualification test program.

3.2.1.2 Test Plan

All rocket motors assigned to the development test program will be subjected to various environmental treatments (e.g., temperature cycling, vibration, temperature gradient, accelerated aging, and drop test) prior to static testing. The launch escape motors will be tested according to the schedule given in Figure 3-1. Parallel with the launch escape motor testing will be launch escape motor igniter testing. Test firings of the initiator will include firings into pellet baskets, pyrogens, and full-scale motors.

3.2.1.3 Equipment

Test equipment for the launch escape motor development program will consist of a three-component thrust stand, motor-conditioning equipment,

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motor-handling equipment, and a data acquisition system. Altitude ignition simulation equipment, hydrotest, and vibration equipment will also be required.

3.2.1.4 Facilities

The launch escape motor development program will be performed at the existing facilities of the Lockheed Propulsion Company at Redlands and Potrero, California.

3.2.1.5 Test Schedule

The test schedule for the launch escape motor development program is shown in Figure 3-1.

3.2.2 Pitch Control Rocket Motor Tests (Lockheed Propulsion Company)

3.2.2.1 Objective

Completion of the development program for the pitch control motor will verify the motor performance and assure the best motor component design. Data from the igniter and motor static firings will be used for ballistic performance analyses. A number of static firing tests are scheduled for demonstration of low and intermediate impulse pitch control motor performance. Environmental treatments imposed upon the test units prior to firing will help to firmly establish the motor design before qualification testing is attempted.

3.2.2.2 Test Plan

All rocket motors assigned to the development test program will be subjected to various environmental treatments (e.g., temperature cycling, vibration, temperature gradient, accelerated aging, and drop test) prior to static testing. The pitch control motor will be tested according to the schedule given in Figure 3-2. Parallel with the pitch control motor testing will be pitch control motor igniter testing. Test firings of the initiator will include firings into pellet baskets and full-scale motor firings.

3.2.2.3 Equipment

The test equipment utilized for the pitch control motor development program will include a single component thrust fixture, an instrumentation and data acquisition system, and temperature conditioning equipment. Hydrotest fixtures and equipment, vibration equipment, and vacuum equipment will also be required.

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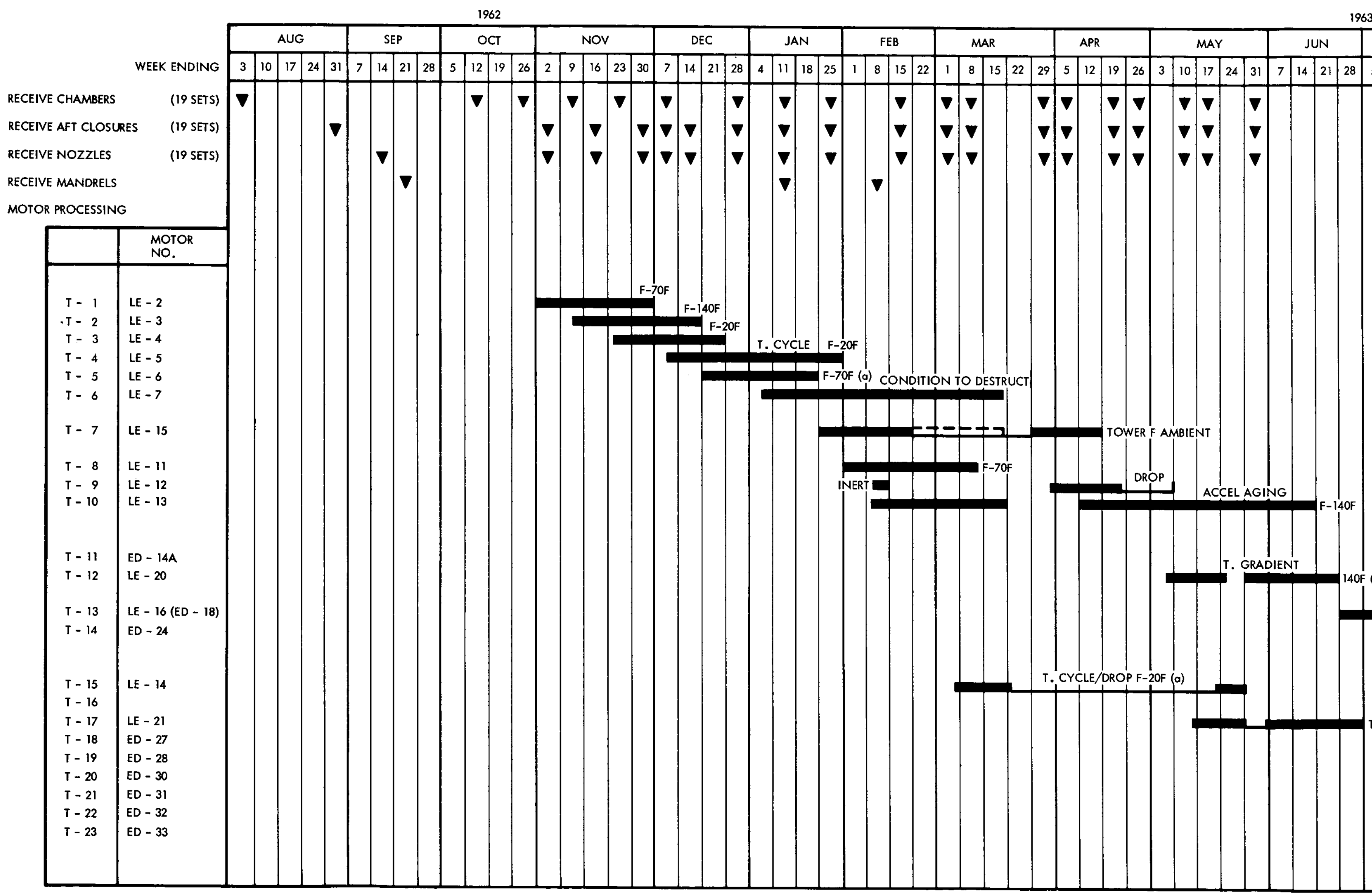
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WEEK ENDING
3 10 17 24 31 7 14 21 28 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 1 8 15 22 1 8 15 22 29 5 12 19 26 3 10 17 24 31 7 14 21 28
RECEIVE CHAMBERS (19 SETS)
RECEIVE AFT CLOSURES (19 SETS)
RECEIVE NOZZLES (19 SETS)
RECEIVE MANDRELS
MOTOR PROCESSING
MOTOR NO.
T - 1 LE - 2
T - 2 LE - 3
T - 3 LE - 4
T - 4 LE - 5
T - 5 LE - 6
T - 6 LE - 7
T - 7 LE - 15
T - 8 LE - 11
T - 9 LE - 12
T - 10 LE - 13
T - 11 ED - 14A
T - 12 LE - 20
T - 13 LE - 16 (ED - 18)
T - 14 ED - 24
T - 15 LE - 14
T - 16
T - 17 LE - 21
T - 18 ED - 27
T - 19 ED - 28
T - 20 ED - 30
T - 21 ED - 31
T - 22 ED - 32
T - 23 ED - 33
F-70F
F-140F
F-20F
T. CYCLE
F-20F
F-70F (a)
CONDITION TO DESTRUCT
TOWER F AMBIENT
F-70F
INERT
DROP
ACCEL AGING
F-140F
T. GRADIENT
140F
T. CYCLE/DROP F-20F (a)

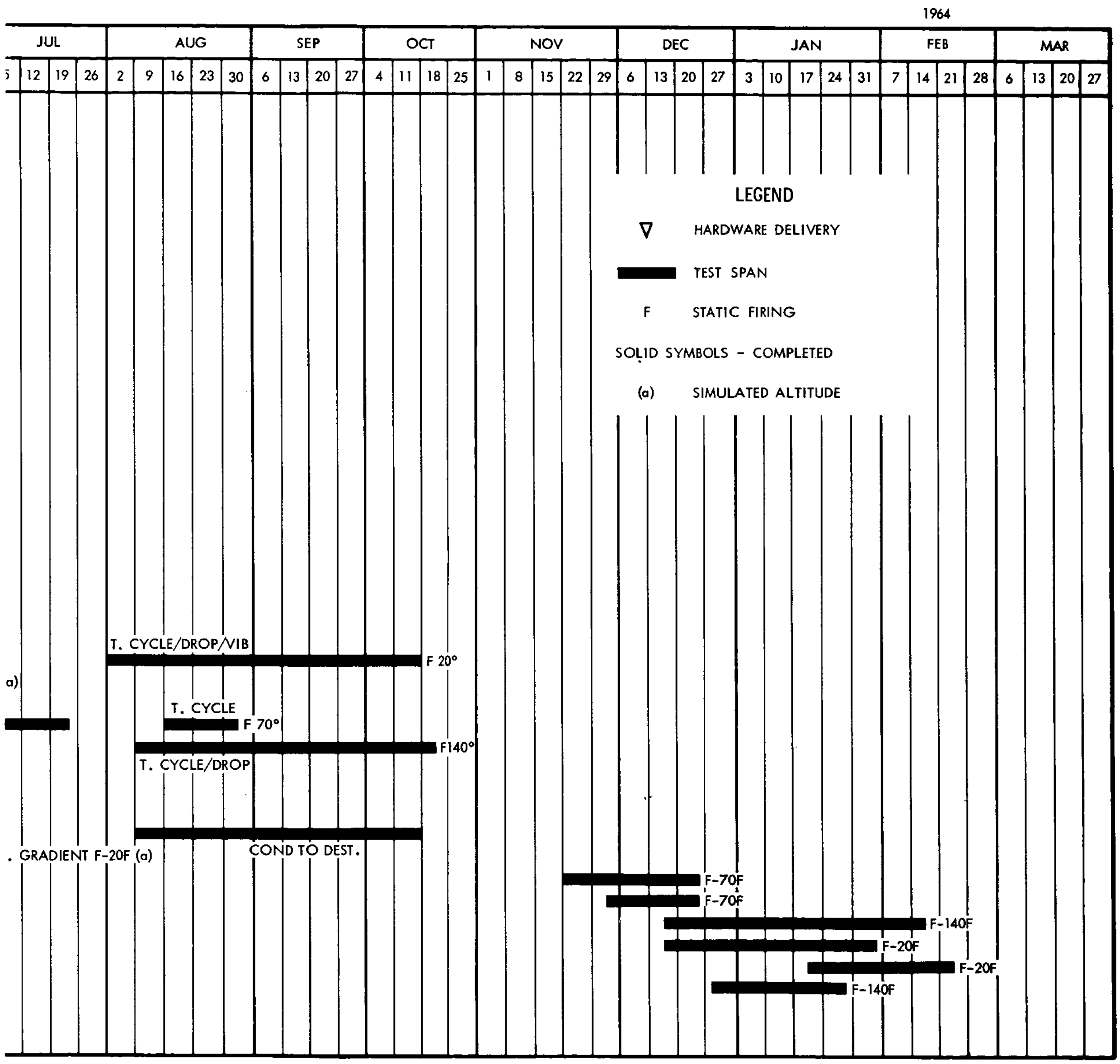

Figure 3-1. Apollo Launch Escape Motor Development Schedule

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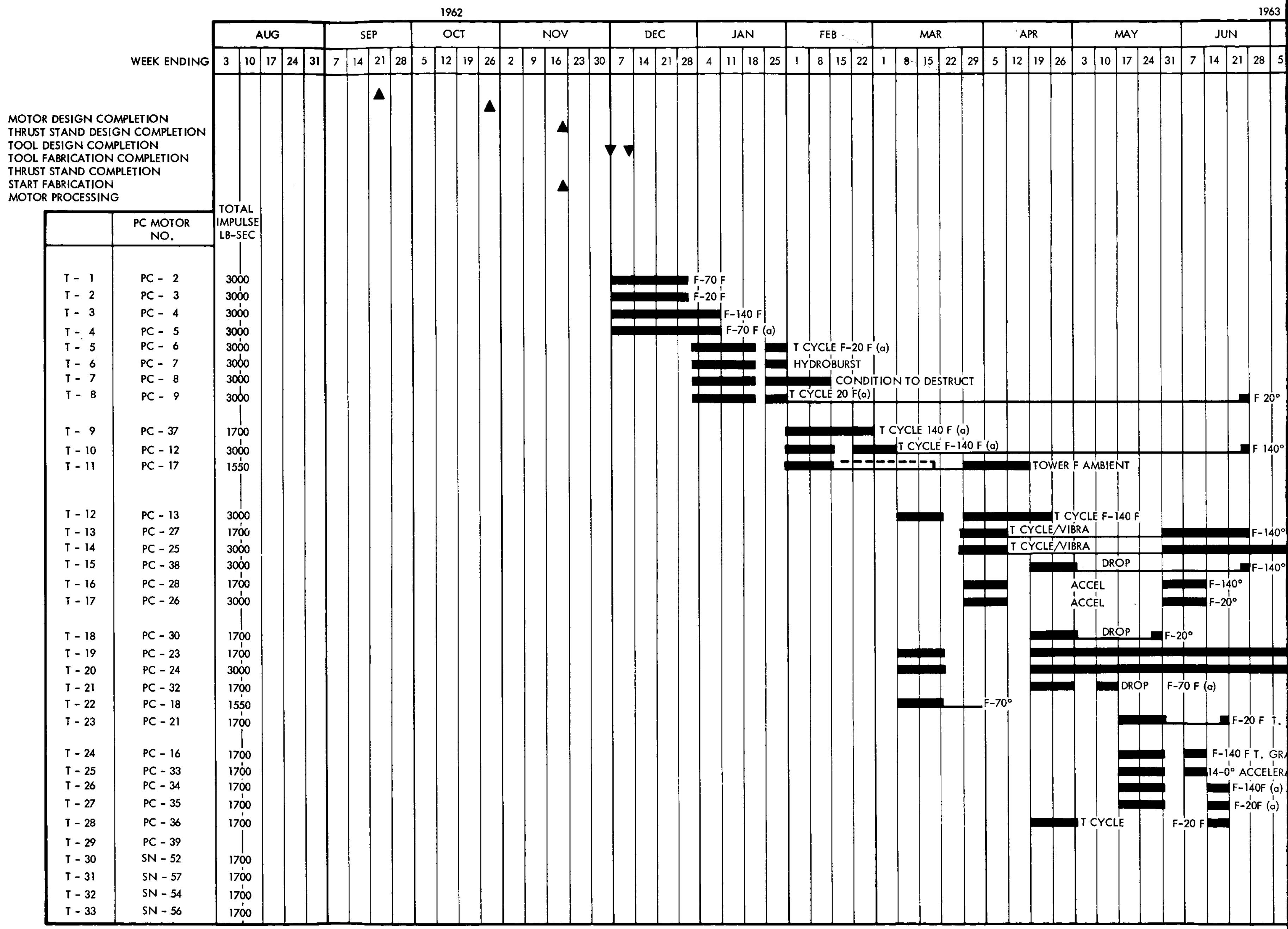
NO



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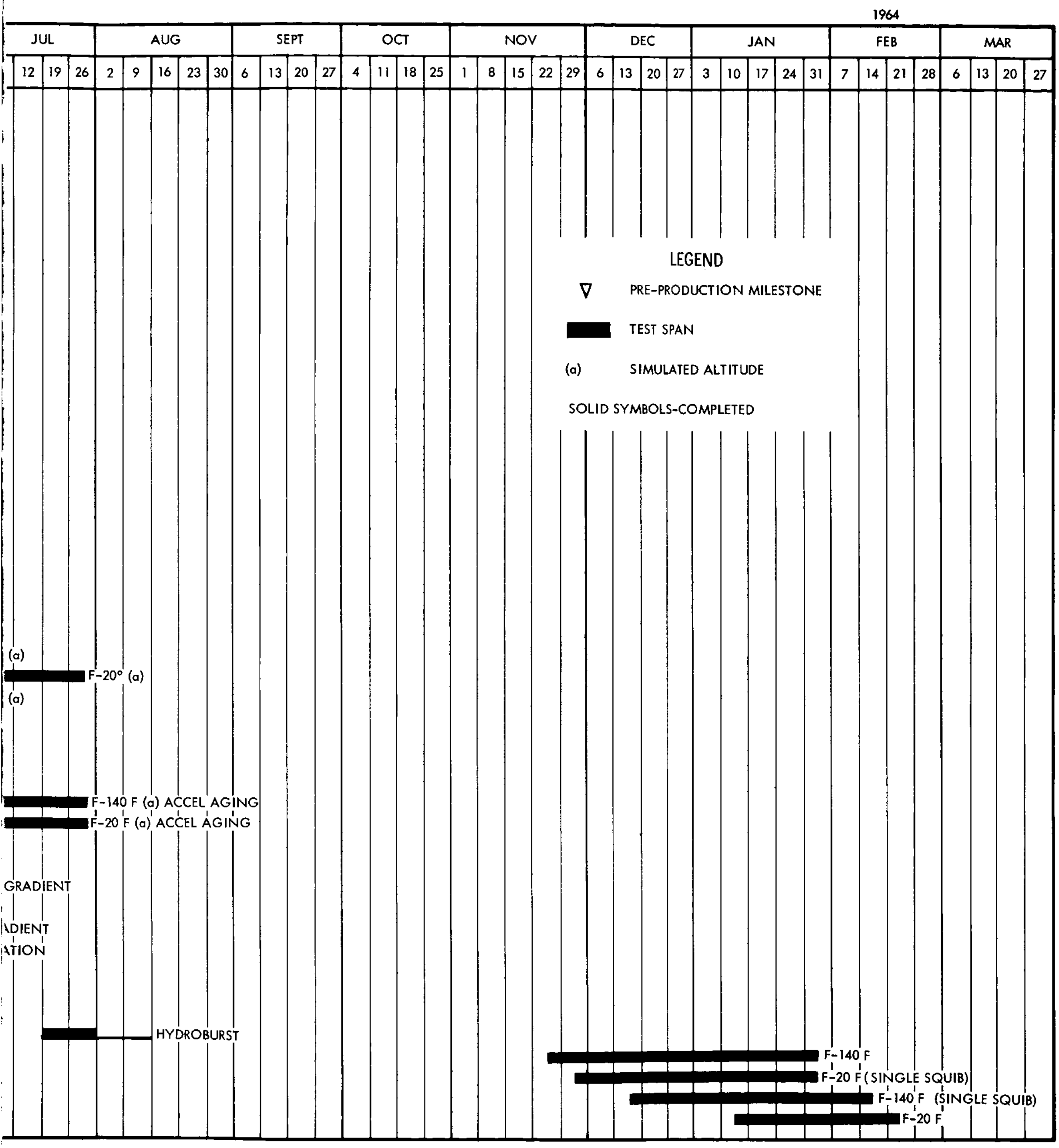

Figure 3-2. Apollo Pitch Control Motor Development Schedule

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3.2.2.4 Facilities

The pitch control motor development program will be performed at the existing facilities of the Lockheed Propulsion Company at Redlands and Potrero, California.

3.2.2.5 Test Schedule

The schedule for the pitch control motor development program is shown in Figure 3-2.

3.2.3 Tower Jettison Rocket Motor Tests (Thiokol Chemical Corporation)

3.2.3.1 Objective

The tower jettison motor will undergo a development program in order to demonstrate its ability to perform as required after having been subjected to various environmental treatment. Development testing will optimize component designs, identify design margins, and result in a tower jettison motor in a finalized configuration for qualification testing.

3.2.3.2 Test Plan

All rocket motors assigned to the development test program will be subjected to various environmental treatments (e.g., temperature cycling, vibration, temperature gradient, accelerated aging, and drop test) prior to static testing. The tower jettison motor will be tested according to the schedule given in Figure 3-3. Parallel to the tower jettison motor testing will be tower jettison motor pyrogen ignition system testing. Pyrogen test firings will demonstrate the suitability of the igniter cartridge and the pyrogen design.

3.2.3.3 Equipment

Test equipment utilized in the tower jettison motor development program will include two three-component thrust stands, instrumentation and data acquisition systems, temperature conditioning equipment, and vibration equipment. Hydrotest equipment, vacuum equipment for simulated altitude ignition testing, and motor handling equipment will also be used.

3.2.3.4 Facilities

The tower jettison motor development program will be conducted at the existing facilities of the Thiokol Chemical Corporation at the Elkton, Maryland, plant. The support of the Arnold Engineering Development Center simulated altitude facilities will be required for two development tests.

3.2.3.5 Test Schedule

The subcontractor's schedule for the tower jettison motor development program is shown in Figure 3-3.

3.2.4 Qualitative Evaluation of LES and TJM Plume Impingement Effects on Command Module Windows

3.2.4.1 Objective

The test objective is to qualitatively evaluate the modes of command module window contamination due to primary and secondary LES and TJM plume impingement and the resulting optical properties of the command module windows.

3.2.4.2 Test Plan

Tests will be performed concurrent with the Lockheed batch motor firings using command module window glass, ablative material, thermal control paint, and boost cover cork samples, with appropriate mounting structure and high-speed motion picture coverage to evaluate worst-case window sooting and abrasion due to plume impingement from the batch motors. The data of these tests will be used as a criterion to determine the effects of the following:

1. Direct exhaust plume impingement
2. Partial deflection of the plume flow field
3. Redeposition of burnt cork from boost cover
4. Abrasion of glass surface from solid particle impingement

Surface pressure data and photographic coverage will be obtained for each of the six runs.

After firing, the specimen will be subjected to optical and chemical analysis to determine the degree of degradation of the visibility through the windows and the origin of the soot deposited on the glass surface.

3.2.4.2.1 Test Requirements. The glass specimen will be subjected to a one-second impingement from the batch motor exhaust plume. The position of the glass will be varied for each of the six runs. The first two firings will subject the glass to direct plume impingement. The third and fourth firings will have an angle piece attached to the fixture holding the

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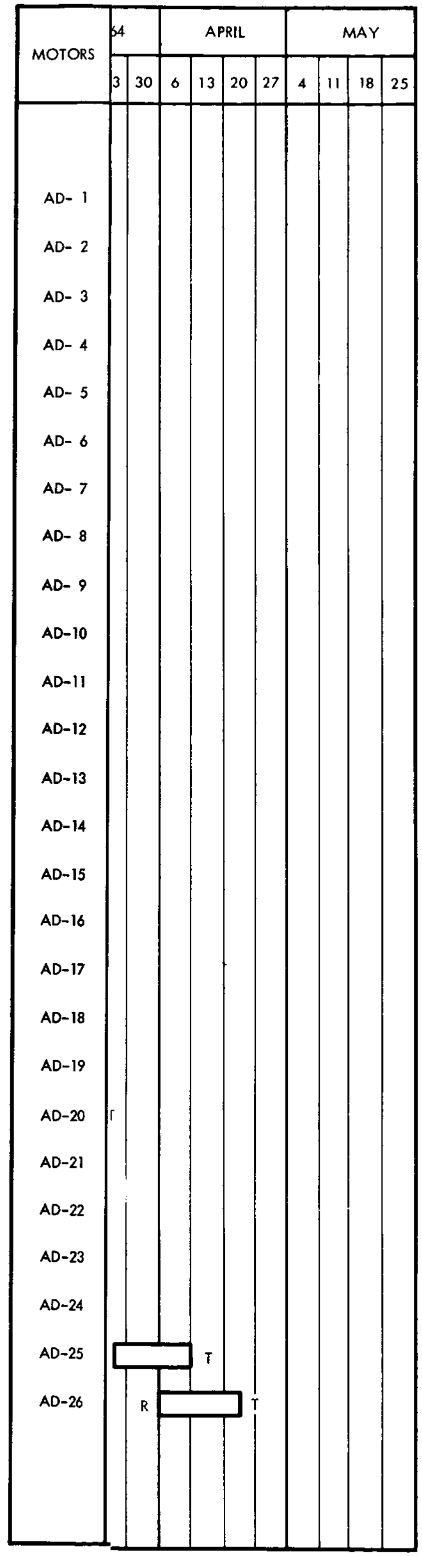

:tison Motor Development Schedule

[redacted]

glass sample to simulate the deflection of the plume flow over the glass surface. Firings number five and six will have samples of ablative material or boost cover cork glued to the angle attachment in order to determine what portion of the soot originates from them.

Still and motion picture coverage of the entire setup and plume, and of the first wavelength of the plume with the specimen injected will be required for visual study of the nature of the plume impingement on the glass.

3.2.4.2.2 Data Requirements. The following data will be required.

1. Static impingement pressure versus time
2. Motion picture coverage of first wavelength of plume with specimen injected
3. Still photo of setup and entire plume
4. Still photo of setup and specimen after firing

3.2.4.3 Equipment

1. Six 1/2 by 4 by 5 inch reconstructed quartz (code 7940) glass samples
2. Six batch motors with D_e = .953 inches, P_c = 2000 ± 200 psi, T_c = 4600 F
3. One sample of ablative material with thermal control paint and one sample of boost cover cork
4. One pressure transducer

3.2.4.4 Facilities

Tests will be conducted at Lockheed Propulsion Company, Redlands, California.

3.2.4.5 Test Schedule

Tests will be run during the months of June and July, 1964, concurrent with existing Lockheed schedules for batch motor firings.

[redacted]

4.0 EARTH LANDING SYSTEM

4.1 SCOPE

This section describes engineering development tests to be conducted by Northrop-Ventura and S&ID. Northrop-Ventura will be responsible for the design and development test of the parachutes and parachute deployment subsystems. S&ID will be responsible for the development test program of the crew shock-attenuation subsystems. The objective of these tests is to develop a system which will mitigate the transient deceleration loads due to landing impact and which will insure safety for the crew, structure, and equipment.

Qualification and reliability tests will be covered in Volume III.

4.2 SUBCONTRACTOR TEST PLAN (NORTHROP-VENTURA)

4.2.1 Parachute Subsystem Tests

4.2.1.1 Objective

The objective of this test program is to develop and prequalify the parachute subsystem for Apollo per S&ID Procurement Specification MC 901-0001.

4.2.1.2 Test Plan

This plan is basically divided into two categories, laboratory testing and aerial drop testing.

Each of these categories is in turn divided into development and prequalification phases.

4.2.1.2.1 Laboratory Development Tests. The development phase of the laboratory testing consists of tests on materials, components, and circuits used in parachutes, parachute disconnects, parachute mortars, and sequence control units to (a) determine their application suitability, (b) acquire design or process information, and (c) develop assurance that the product will successfully complete the prequalification phase.

[redacted]

4.2.1.2.2 Laboratory Qualification Tests. The qualification phase of the laboratory testing includes design proof tests and mission life tests. The former consist of tests for (a) climatics, (b) electromagnetic interference and explosion proofing, (c) prelaunch environments (static firing), and (d) sequentially applied maximum mission environments, followed by tests to failure for verification of critical environmental and functional design margins. Mission life tests consist of exposure to single or combined mission environments employing nominal values of expected environmental stresses.

4.2.1.2.3 Aerial Drop Development Tests. The development phase of the aerial drop testing consists of approximately 16 tests on drogue parachutes, 39 individual main parachute tests, 23 clustered main parachute tests, and finally on the complete system for design verification purposes. A total of approximately 89 are scheduled, including 11 complete system tests employing boilerplates 3 and 19. Data to be obtained consists of parachute force versus time; position versus time; temperature, barometric pressure, and winds versus altitude; and motion picture coverage to include ground-to-air, air-to-air, and a camera on board the drop vehicle. These data will be used to verify that design objectives are being met or to guide the appropriate corrective action.

4.2.1.2.4 Aerial Drop Prequalification Tests. The prequalification phase of the aerial drop testing consists of approximately three drops of boilerplates 6 and 19, including simulation of operational extremes anticipated for normal entry and mission abort conditions. Data requirements are the same as for paragraph 4.2.1.2.3.

4.2.1.3 Equipment

RB-66 and C-130 aircraft, from the 6511th Test Group (Parachute), at El Centro, will normally be used for dropping simple weight bombs and specially constructed parachute test vehicles which simulate the Apollo parachute compartment.

A specially modified C-133A aircraft, operated by the Douglas Aircraft Company, will be used for dropping the Apollo boilerplates.

Equipment at the drop test range includes: cinetheodolite stations, tracking radar, a Rawin system for determining atmospheric conditions from ground to drop altitude, and a data telemetering system.

4.2.1.4 Facilities

Laboratory tests will be performed at the existing facilities of the Northrop-Ventura Corporation, at Newbury Park, California. Aerial drop

[redacted]

tests will be performed at the Department of Defense Joint Parachute Test Facility, Naval Air Facility, El Centro, California. Existing government facilities at El Centro, including an extensively equipped drop-test range, will be supplemented as required by Northrop-Ventura and S&ID.

4. 2. 1. 5 Test Schedule

The schedule for the aerial drop test program is presented in Figure 4-1.

4. 3 S&ID TESTS

4. 3. 1 <u>One-Tenth Scale Model Water Landing and Flotation Test</u>

4. 3. 1. 1 Objectives

Phase A - Obtain preliminary data, in advance of boilerplate tests, on water landing accelerations and stability envelopes using parameters of horizontal and vertical landing velocities and C/M attitudes.

Phase B - Determine flotation, statical and dynamic stability characteristics for intact and damaged cases considering various weights, C. G. locations and simulated sea state using a scaled model vehicle and a model test basin.

4. 3. 1. 2 Test Plan

Phase A - Horizontal velocity is to be applied in increments of five feet per second, from zero velocity until instability (tipping) occurs, with all combinations of the landing parameters in calm water and in a simulated sea state.

Phase B - The following operations will constitute the flotation test plan:

1. Flotation test

2. Statical stability test

3. Dynamic test

From static tests determine static stable positions, range of stability and curves of righting arms and moments. Verify requirements for one-position stability.

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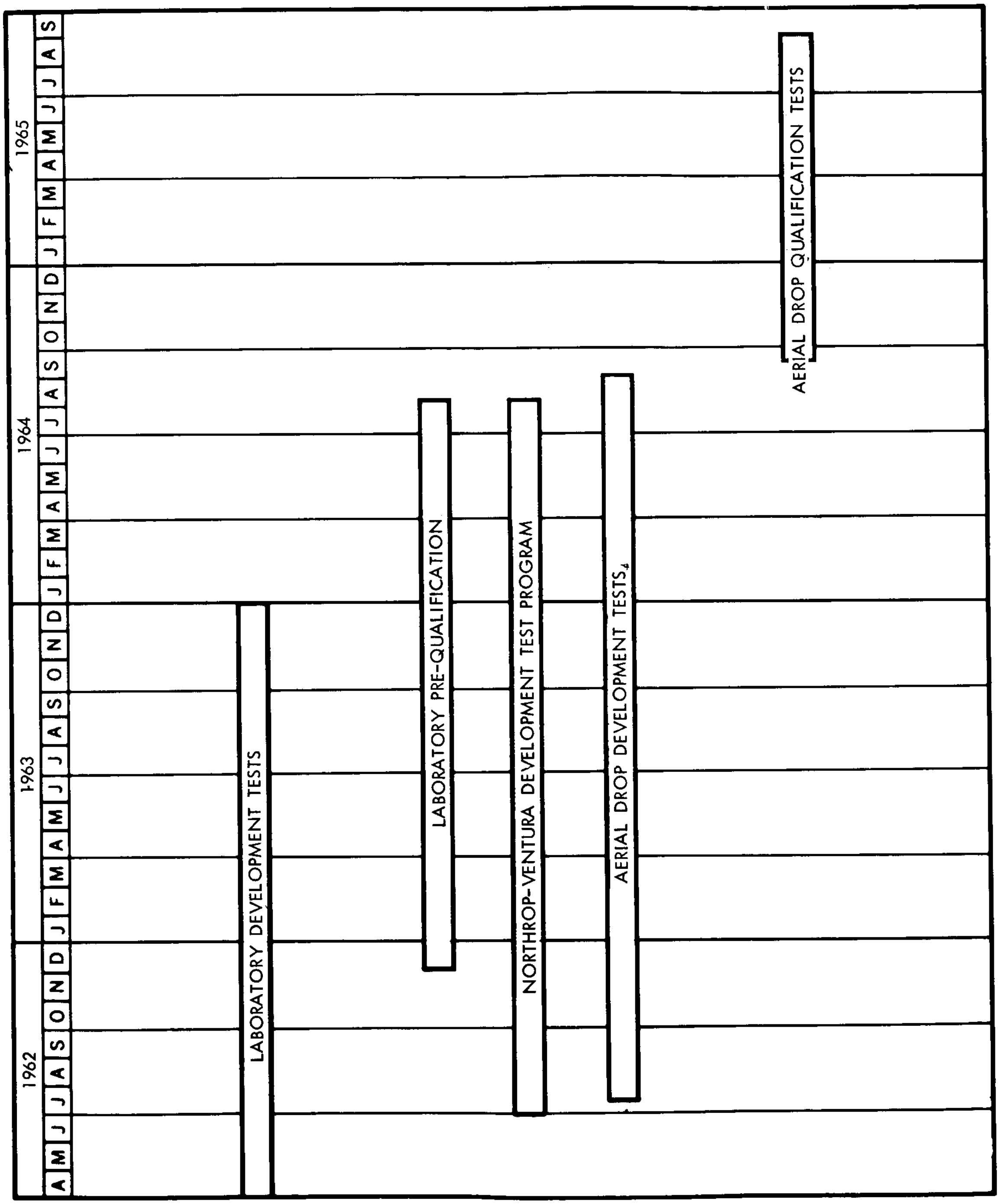

Figure 4-1. Parachute Subsystem Test Schedule

[redacted]

From dynamic tests determine:

1. Vehicle response in a sea state of four
2. Probability of capsizing in various sea states
3. Severity of motion
4. Measurement of drift
5. Motion pictures of vehicle motion
6. Damping action of vehicle

4.3.1.3 Equipment

The equipment necessary for the tests is:

1. Floodable 1/10 scale model of C/M
2. Wave state simulator
3. Force-stroke measuring devices
4. One set of biaxial linear accelerometers
5. Oscillographic recording equipment
6. High-speed motion picture coverage

4.3.1.4 Facilities

The S&ID Space Sciences Lab hydrodynamic towing channel will be used to conduct the test.

4.3.1.5 Test Schedule

Phase A - A preliminary portion of Phase A was completed 1 July 1963.

Phase B - Partial completion of flotation and static stability tests have been made. Preliminary dynamic tests on one-tenth scale model was completed in March 1964. Full scale dynamic tests will be completed by February 1965.

5.0 ENVIRONMENTAL CONTROL SYSTEM

5.1 SCOPE

This section presents an outline of the environmental control system (ECS) design verification and development evaluation tests to be accomplished during Apollo spacecraft development. In order to keep the crew and equipment operating at top efficiency, it is essential that the characteristics of the surrounding atmosphere, including temperature and pressure, be controlled. Test of the ECS will ensure adequate temperature, humidity, oxygen, and pressure control; equipment cooling; and removal of carbon dioxide, toxic gases, and other contaminants. Food, water, waste management, personal hygiene, and crew protection equipment will be developed and evaluated from a mechanical standpoint by means of the ECS breadboard tests.

There are several modes of operation of the ECS for the Apollo vehicle in the command or service module. These modes will be tested separately and in combination, in order to optimize the design and to assure complete reliability of the over-all system.

Testing of the ECS by the subcontractor (AiResearch Manufacturing Company, Los Angeles, California) will be accomplished at four levels: materials, components, subsystems, and system. After testing has established the satisfactory performance of the development components and subsystems at the system level, the designs of the components and subsystems will be optimized to spacecraft status with respect to weight, materials, and finishes.

Materials will be investigated by the subcontractors for their integrity and reliability in Apollo environments. Off-the-shelf components will be tested to confirm performance or to determine design modifications. Newly designed components will be tested to verify design concepts or improvements. Testing of these components will continue until nominal performance requirements are met in selected critical environments.

Performance of the subsystems will be optimized through design changes resulting from tests that are calculated to determine the interactions of the components and the influence of the connecting media.

[redacted]

The required design performance of the system will be obtained through changes resulting from tests calculated to determine the interaction of the subsystem and the influence of the connecting ducts and tubing.

Three major test programs will be conducted by S&ID at the prime contractor facilities. These will consist of an integrated ECS breadboard test, radiator development test, and coldpate test program.

The integrated ECS breadboard test will consist of a complete ECS installed in a pressure vessel having the same internal volume as the spacecraft. The operational characteristics of the system will be monitored during simulated Apollo mission phases.

The ECS radiator test program will consist of placing a thermal coated radiator in a vacuum chamber and evaluating its operational performance during simulated Apollo mission environments.

The coldplate test program will be initiated by performing development type tests on a single coldplate configuration. Upon performance verification a complete ECS network will be assembled in a test fixture simulating the spacecraft structure. The assembled coldplate network will be placed in a vacuum chamber and subjected to a mission profile, simulating time, mission environments, and the electronic equipment heat loads. After demonstrating mission capability, the network will be integrated into the water-glycol subsystem of the ECS breadboard to evaluate and demonstrate integrated system capability.

5.2 SUBCONTRACTOR TEST PLAN (AiResearch)

The subcontractor shall be responsible for the accomplishment of the complete development test program on the environmental control system equipment supplied by the subcontractor. All testing shall be monitored by S&ID.

5.2.1 ECS-GSE Integrated System Development Test

5.2.1.1 Objective

The objective is to determine and optimize the operational performance of ECS and GSE when integrated and tested under simulated count-down conditions.

[redacted]

5.2.1.2 Test Plan

The ECS test procedures will be designed to evaluate the GSE during the conditions encountered during ECS ground operations. Tests will contribute to instrumentation locations and checkout procedures used in spacecraft.

5.2.1.3 Equipment

Calibrated laboratory instrumentation shall be used to monitor system performance.

5.2.1.4 Facilities

Testing will be performed at AiResearch's Los Angeles facility.

5.2.2 <u>ECS System Development Test</u>

5.2.2.1 Objective

The objective is to determine and optimize the performance of an environmental control system complying with the requirements of S&ID procurement specification MC 999-0034.

5.2.2.2 Test Plan

A complete ECS, except for the entry oxygen package, shall be subjected to simulated prelaunch, launch, translunar coast, lunar orbit, entry, and emergency modes of the Apollo lunar mission. Calibrated laboratory equipment shall be used to monitor system performance. The C/M thermal loads, C/M equipment locations, C/M tubing installations, space radiators, electrical installations, electrical power system, supercritical fluid system, and fuel cell water production will be simulated.

5.2.2.3 Equipment

Testing will be performed in an altitude chamber. The chamber will be limited to 1.0 psia command-module-interior minimum pressure. A high-vacuum unit shall provide a vacuum source for evaporator operations.

5.2.2.4 Facilities

Testing shall be performed at the AiResearch Los Angeles facilities.

5.2.3 <u>ECS Subsystem Development Tests</u>

5.2.3.1 Objective

The objective is to determine and optimize the functional and physical configurations of the subsystems required to develop an environmental control system complying with the requirments of S&ID Procurement Specification MC 999-0034.

[redacted]

5.2.3.2 Test Plan

5.2.3.2.1 Water-Glycol Subystem. A water-glycol subsystem and the temperature control components of the cabin temperature control subsystem will be installed in an altitude chamber with simulated suit, cabin, and electronic thermal loads. The tubing installation pressure drops and space radiators will also be simulated. Test runs will be made at laboratory ambient and 5.0 psia pressures with thermal loads varied through a range of -10 percent to +10 percent of analytically predicted values. Subsystem performance will be determined quantitatively. Some areas of specific interest are response time of the temperature control circuits and pump performance.

5.2.3.2.2 Entry Oxygen Subsystem Test. Subsystem characteristics during all mission phases and performance during entry will be determined and optimized.

5.2.3.2.3 Pressure Suit Circuit Subsystem Tests. The suit circuit subsystem will be installed in a vacuum chamber and tested at 5.0 psia and laboratory ambient. Suit pressure drop and crew metabolic rate will be simulated with a metabolic stimuli generator. The suit circuit performance will be determined quantitatively with the interface parameters maintained at analytically predicted values and with the analytically predicted values varied ±10 percent.

The objective of this test is to evaluate component performance for subsystem operation.

5.2.3.3 Equipment

Equipment	Usage
Dynamic recording systems	All phases
Signal conditioning system	All phases
Water-glycol supply cart	All phases
High-vacuum and condenser unit	All phases
Metabolic simulator	All phases (Suit circuit)
Contaminate analyzer	All phases
System vacuum fixture	All phases
Thermal load simulators	All phases
Portable system tester and signal conditioning system	System and integrated system test

[redacted]

5.2.3.4 Facilities

Water-glycol subsystem tests will be performed at AiResearch's Los Angeles facilities. The entry oxygen subsystem will be tested at the Boron, California, facilities of AiResearch.

5.2.3.5 Test Schedule

The test schedule for the subcontractor test plan is shown in Figure 5-1.

5.3 S&ID TEST PLAN

5.3.1 ECS Integrated System (Breadboard) Test

5.3.1.1 Objectives

The Apollo environmental control system breadboard tests are to be conducted to study and evaluate the ECS as an integrated unit. The ECS will be installed in the spacecraft location in a pressure vessel having the same internal volume as the spacecraft. The test will be conducted in a vacuum chamber and will simulate prelaunch, launch, earth orbit, trans-lunar coast, lunar orbit, reentry, and postlanding phases of the Apollo mission. Emergency conditions such as a micrometeorite puncture will also be simulated. The results of these tests will produce an integrated ECS that will meet design requirements.

The breadboard system will also be used for verifying the performance of new components and subsystems resulting from design improvements or changes in system performance requirements.

The ECS breadboard test program will support the development of the ECS and provide data to prove design concepts by evaluation of individual components, subsystems, systems, integrated systems and their interactions.

Testing will be performed to demonstrate system capability to provide a conditioned atmosphere for pressure-suit operation.

Testing will be performed to demonstrate system capability to provide a shirtsleeve environment for the command module.

Testing will be performed to determine system out-gassing and demonstrate system capability in removal of toxic atmospheric constituents. A gas analyzer will be utilized to monitor the command module atmosphere.

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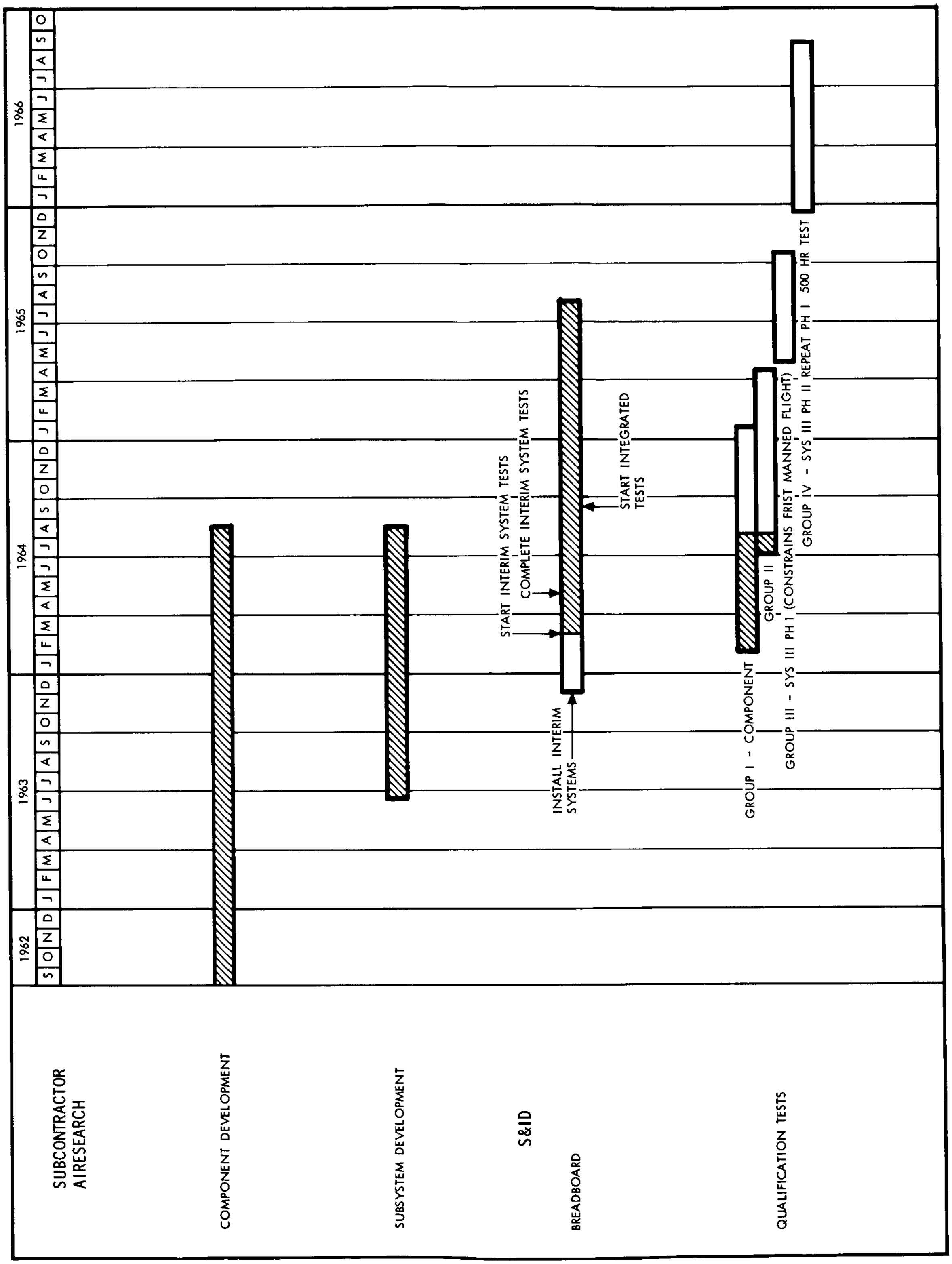

Figure 5-1. Environmental Control System Test Schedule

[redacted]TIAL

Testing will be performed to demonstrate system capability to provide thermal control to the required equipment in the command and service modules.

Testing will be performed to demonstrate the system capability of providing a habitable environment with component failure and/or emergency conditions imposed on it by design requirements.

5.3.1.2 Test Plan

A pressure vessel, or environmental simulator, having the same interior geometry as the spacecraft command module, with the C/M components installed in their spacecraft location, will be tested in the altitude chamber. The test parameters imposed will (1) subject the system equipment to the design parameters to develop an integrated environmental control system and (2) demonstrate environmental control system capability to meet design requirements. These parameters will include all Apollo mission phases.

The equipment installed in the command module will be the first tested with the interface equipment simulated and operating within the system parameters. The simulating equipment will be replaced as the interface units become available, thus integrating a complete environmental control system with electrical power and cryogenic interfaces with the fuel cell. The integrated system will be operated through a complete Apollo mission, including all modes.

Command module crew compartment pressure control will be tested through the complete simulated mission of four test phases. Cabin pressure at prelaunch and launch will be 14.7 to 5.0 psia, including the time rate change. Cabin pressure during the flight phase will be monitored for normal maintenance of 5.0 psi with simulated continuous inherent command module leakage of 0.2 pounds of gas per hour during a 14-day mission.

Tests will be conducted to verify the pressure control system maintenance of 5.0 to 3.5 psia during a simulated puncture of the spacecraft for a minimum of 5 minutes. The puncture will be simulated by a one half inch orifice solenoid valve.

The pressure suit system demand regulator will be tested during emergency operation for maintenance of 3.5 psia, while the cabin is at 1×10^{-4} Torr vacuum and all systems operating. They must have the capability to operate continuously in this environment for a four-day period. The cabin fan will not be operating during vacuum conditions and, therefore, does not have to meet these requirements.

[redacted]

The breadboard test facility will be man-rated, and tests will be conducted to verify the capability of the ECS to provide a habitable environment for three crew members during a 14-day simulated Apollo mission. An airlock will be utilized for rescue operations. Crew protection will be provided at all times by monitoring the crew performance and C/M interior with TV cameras, by maintaining audio contact, and by using biomedical instrumentation.

The following parameters will be monitored during human occupancy tests to verify system performance:

1. Oxygen supply
2. Carbon dioxide removal
3. Water removal
4. Temperature and pressure control
5. System leakage
6. Manual overrides, controls, and redundancies
7. IFTS - controls and displays
8. Food storage and preparation
9. Fecal storage
10. Urine disposal

5.3.1.2.1 Requirements. The breadboard test requirements are:

Pressure	
C/M external	Atmospheric to 1 x 10^{-4} Torr
C/M internal	Atmospheric to 1 x 10^{-4} Torr
Rate of change	Apollo launch profile
Temperature	
C/M interior wall	70 to 120 F (reentry)
Thermal loads	
External C/M	-430 Btu/hr to +1200 Btu/hr (not including reentry)

Metabolic load	
Three men (shirt sleeve)	at rest and active
Three men (pressure suit)	at rest and active
Space radiator heat sink	
Heat absorption rate	10,000 Btu/hr
Type of transmission	
Radiate only at pressure	1×10^{-4} Torr

5.3.1.3 Equipment

A pressure vessel having the same internal volume as the spacecraft is required to house the breadboard system. Heating equipment with adequate controls is required for simulation of the thermal energy generated by spacecraft equipment, other than the ECS. A metabolic simulator is needed to provide a three-man metabolic load on the ECS. The simulator is to provide for any combination of men in/out suits.

An interim cryogenic storage system simulator is to provide 900 ± 25 psia oxygen at a maximum rate of 40.2 lb/hr flow to the oxygen pressure regulators. An interim power supply is to be furnished to simulate the fuel cell and inverters.

Additional support equipment will be required for the human occupancy test. (See Figure 5-2) The test capsule will be designed for a ΔP of 52 psi. Quick-opening hatches will be provided for the test capsule and the altitude chamber. An airlock will be utilized and will be maintained at 5 psi during manned test. An auxiliary air supply will provide rapid repressurization of the test capsule, airlock, and chamber. An auxiliary oxygen supply to the test capsule also will be available. Continuous monitoring of the crew will be provided by audio, visual (TV cameras), and biomedical instrumentation. Fail-safe and manual overrides will be installed on all critical equipment.

Fire protection of the crew members will necessitate the use of non-arcing or sealed electrical and electronic equipment. Electrical overloading protection and emergency electrical power shut-off to test capsule will be provided. A nitrogen purge to the test capsule will be a standby feature.

5.3.1.3.1 <u>Power Requirements.</u> Power source requirements are:

1. 115 volts, 3 phase, 400-cycle wye power

2. 28 volts, dc, power

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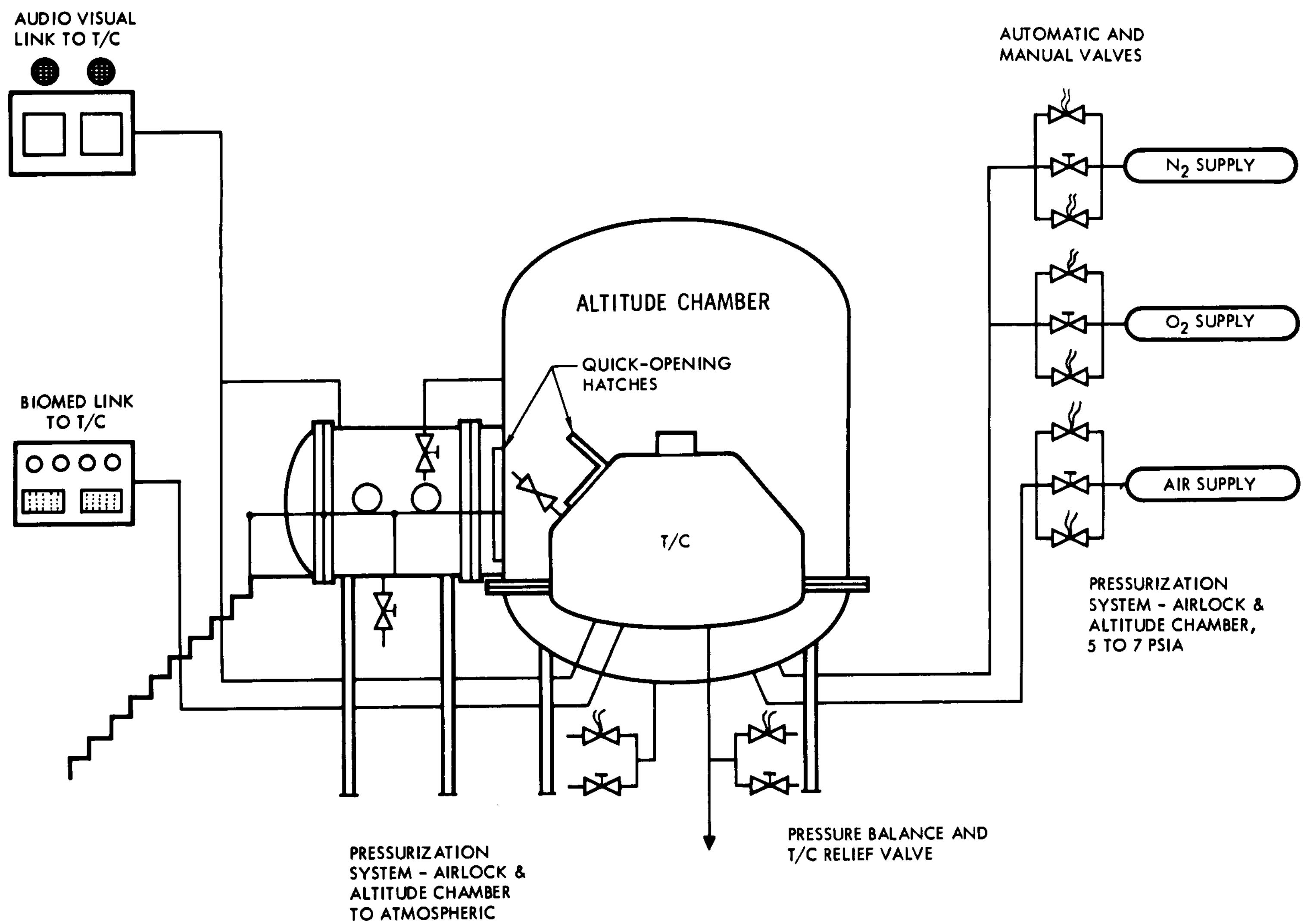

Figure 5-2. Proposed Man-Rated ECS Test Facility

An interim space radiator simulator with a heat absorption rate of 14,000 Btu/hr is required. A pump is to be supplied with a capacity of 200 ± 10 lb/hr and with an outlet pressure of 66 ± 10 psia maximum. The outlet temperature variation is from +45 F to a -30 F with an inlet temperature of +140 F maximum.

A nitrogen supply system is required to provide dry nitrogen for purging and leakage testing the environmental control system, cryogenic system, and the command module. The pressure requirements are 7500 psig for the oxygen reentry, 900 psi for the cryogenic oxygen, 250 psi for the hydrogen, 100 psig for the oxygen regulator, and 9 psig for C/M.

A thermal energy absorber is required that will absorb the radiant thermal energy load of space radiators in an ambient pressure of 1×10^{-4} Torr. The energy exchange rate is 10,000 Btu/hr maximum. Thermal equipment with adequate controls will be used to simulate the reentry thermal load and the associated internal zoned wall temperatures. The maximum wall temperature is 125 F.

5.3.1.4 Facilities

An altitude or vacuum chamber is required in which the environmental simulator (including the breadboard system), space radiator, and cold plates are to be tested at each of the Apollo mission modes. The facility is to be suitable for tests involving human occupancy.

A vacuum pumping system is required to supply the pressure equivalents for the mission flight simulation. The required pressures range from ambient atmospheric to 0.11 psia under dynamic conditions and 1×10^{-4} Torr under static conditions. The pumping system is to be capable of providing a pressure proportioned to the time profile of the Apollo launch and is illustrated in Figure 5-3.

An area is required to house the altitude (vacuum) chamber, instrumentation, controls, pumping system, interface simulators, and a data-collecting system. (See Figure 5-4.)

5.3.1.5 Test Schedules

The integrated breadboard system test schedule is shown in Figure 5-1.

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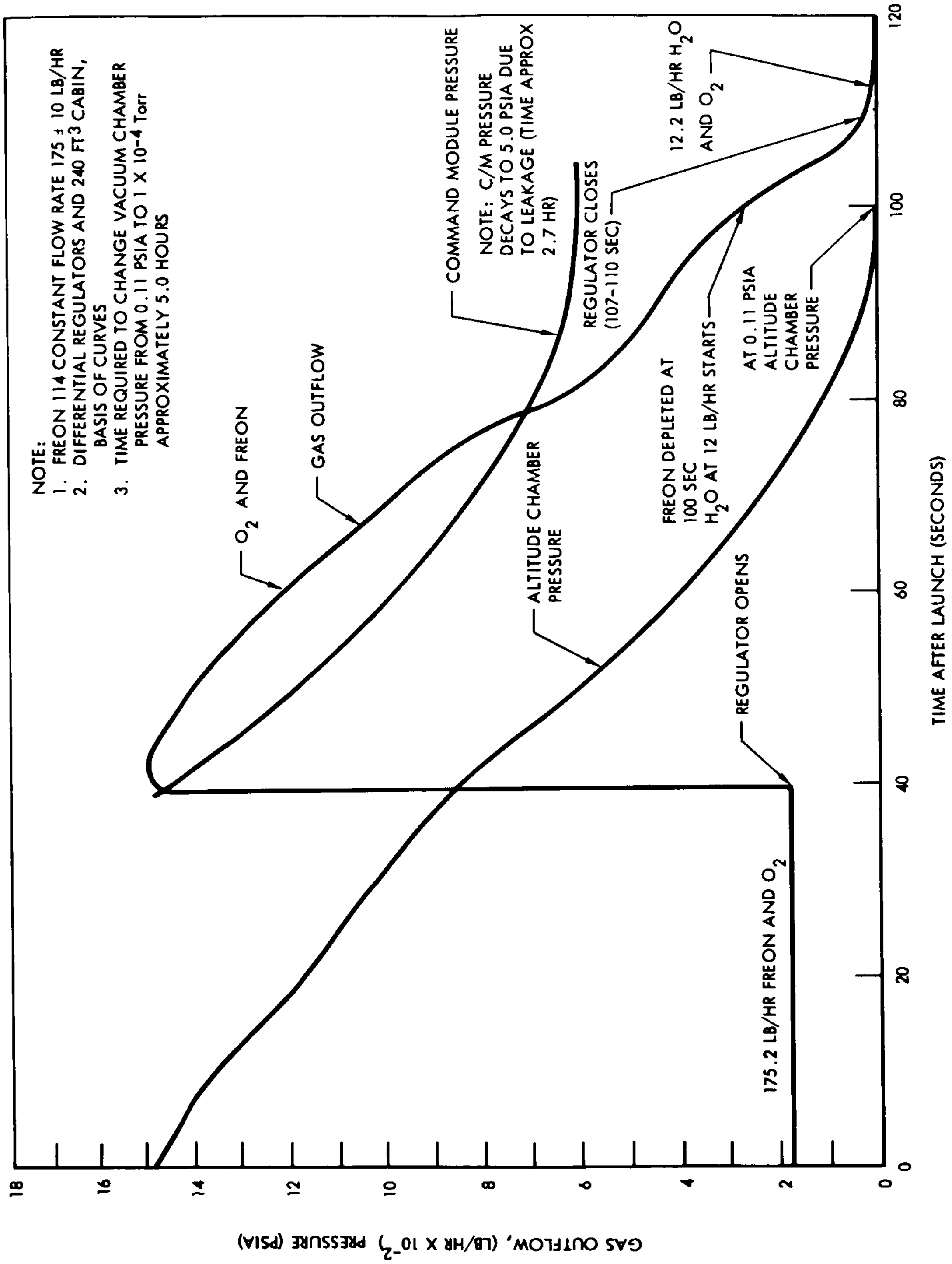

Figure 5-3. Apollo Launch Profile—Vacuum Chamber Gas and H_2O Loads

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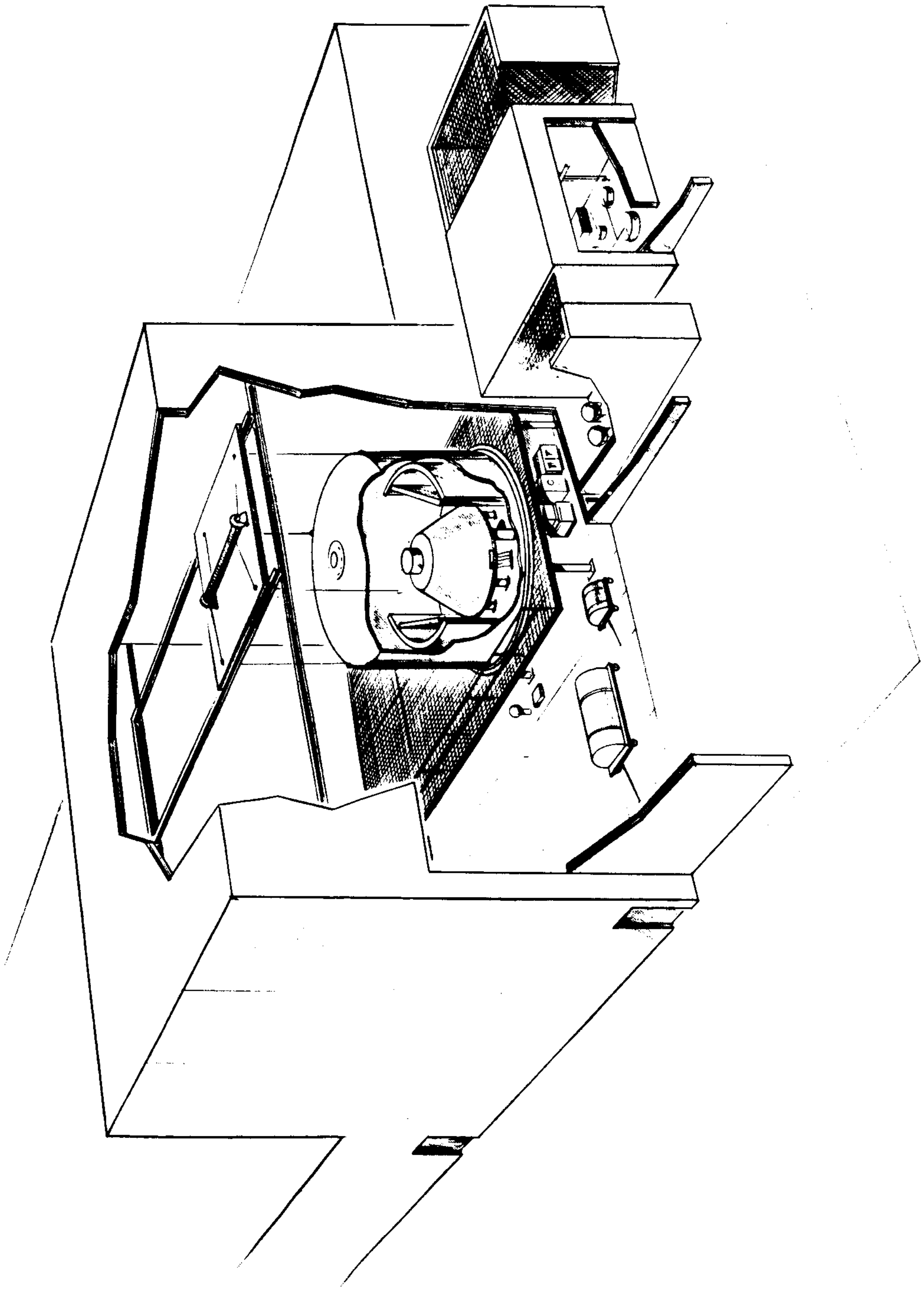

Figure 5-4. Proposed Facility—Integrated (Breadboard) Environmental Control System Test Program

[redacted]

5.3.2 Radiator Test Plan

5.3.2.1 Objective

The Apollo ECS radiator test program will be conducted at S&ID facilities. The panels will be subjected to natural (climatic) and induced environmental conditions to verify design requirements during installation, transportation, handling, storage, and simulated Apollo mission profiles.

5.3.2.2. Test Plan

The test plan will be divided into two programs: the development program and the qualification program. Each program will specify the test requirements desired and the method to be used for testing radiator panels.

Tests will evaluate and demonstrate the capability of the ECS radiator panels to provide a water-glycol heat dissipator for the thermal loads generated in the command and service modules during the various Apollo mission environments. (Ref. Figure 5-5, 60 sq ft radiators for typical lunar orbital mission.)

5.3.2.3 Test Requirements

1. Determine the ΔP of water-glycol solution through the radiator tubing under various flow rates and temperatures.
2. Determine equilibrium temperature of the radiator in the space chamber, using coolant flow rates that simulate Apollo mission environmental conditions.
3. Determine the effect of an unbalanced coolant upon two parallel panels.
4. Determine the temperature transients with sudden changes in external and internal loads.
5. Determine temperature gradient along fin and tubing versus coolant flow rate.
6. Determine edge effects of extended fin in space chamber.

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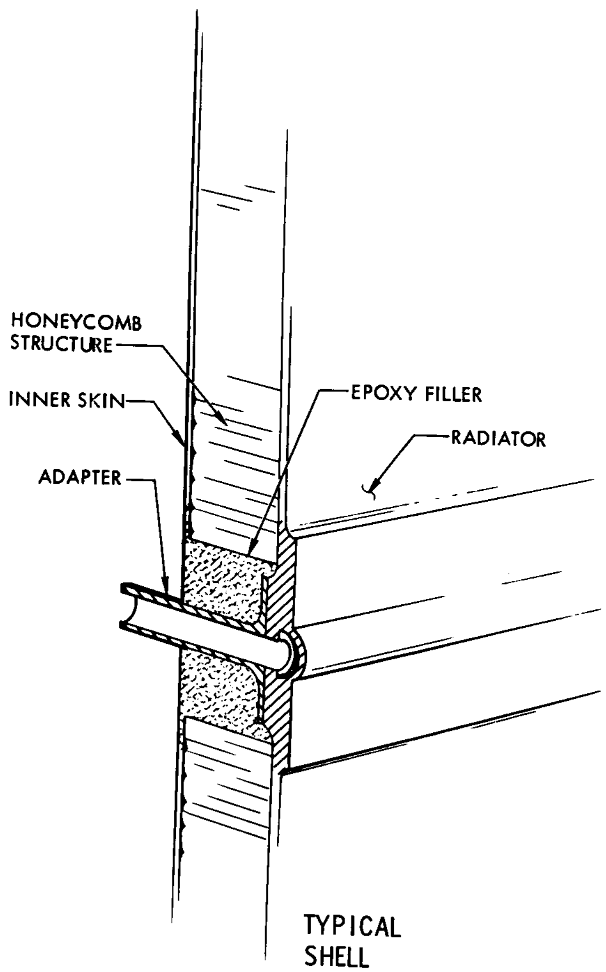
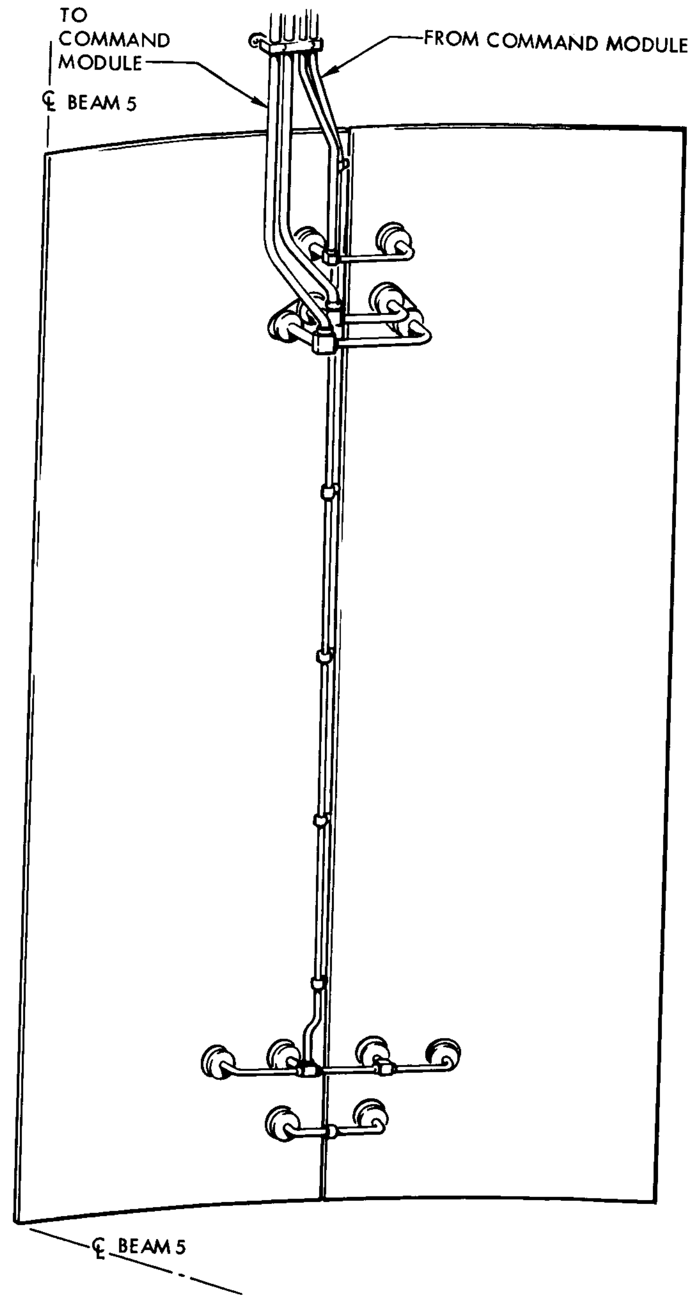
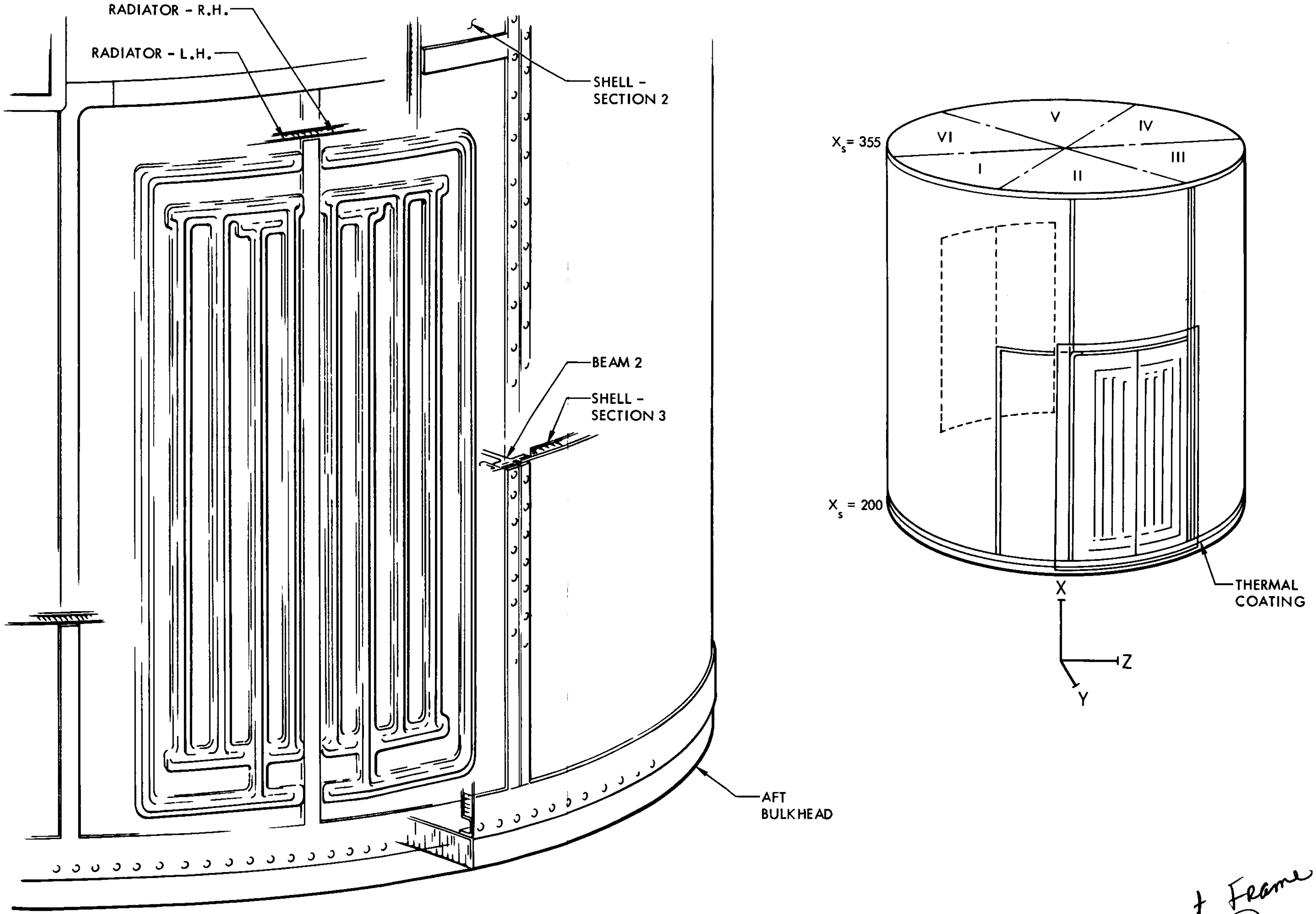


TYPICAL SHELL PENETRATION



RADIATOR-SECTION 5 (HONEYCOMB PANEL NOT SHOWN)



RADIATOR-SECTION 2

Fold-out Frame (2)

Figure 5-5. Radiators (60-sq ft) for Lunar Orbital Mission

7. Verify thermal coating requirements of solar absorptivity (α) of 0.15 and an infrared emissivity (ϵ) of 0.95.

8. Evaluate material and finishes compatibility.

9. Evaluate and demonstrate integrated system performance.

5.3.2.4 Tests

The following tests are required for the development and qualification program of the radiator panels.

5.3.2.4.1 Development Test. The development testing is divided into three areas:

1. Preliminary testing

2. Environmental testing

3. Performance testing

Development Tests will provide data on flow, temperature, thermal properties, space environment, and full-environment simulated operation of radiator panels for any re-design requirements needed.

5.3.2.4.1.1 Preliminary Tests:

1. Receiving and Inspection will check the radiator for conformance to design, specification, and fabrication requirements as per Drawings No. V17-615002, V17-616005, and SCD ME367-006.

2. Leakage Test - EDL will perform the following leakage test. Install radiator panel in a test fixture and apply an air pressure of 150 ± 5 psig and hold for one hour. Record any leakage or variations. A helium leak detector test or an ambient water immersion test may be used if approved by ECS.

3. Proof-Pressure Test - EDL will perform the proof-pressure testing. Install radiator panel in a test fixture and apply an internal hydrostatic proof-pressure of 150 ± 5 psig at ambient conditions and hold for one hour. Repeat leakage test after proof-pressure test.

Page 5-18 deleted

5.3.2.4.1.2 Environmental Test. The following tests will be performed to determine the structural integrity of the radiator panels when subjected to the natural (climatic) and induced environmental conditons which the radiator panels must withstand. All panels of each test will be checked.

1. Shock Test - Place radiator panel with support on test fixture for impact shock along the major lateral axis in both directions and along the longitudinal axis (flight axis) in both directions. Fill radiator panels with ethylene-glycol water solution and pressurize to 150 ± 5 psig. Subject panel to the following shock levels:

   25g for 11 ± 1 millisecond (triangular wave)

   25g for 8 ± 1 millisecond (sine wave)

   25g for 6 ± 1 millisecond (square wave)

   Above shocks are required in both directions along each of the major axes of the radiator panel.

   Perform leakage test specified in paragraph 5.3.2.4.1.1 upon completion of shock test.

2. Vibration Test - Place radiator panel with support on test fixture for vibration along each of the lateral axes and along the longitudinal axis. Fill the radiator panels with ethylene-glycol water solution and pressurize to 150±5 psig. Subject the panel to the following conditions along each axis:

   a. At a frequency of 320 cps, apply 40-g loading per panel nodal pattern observed in acoustic evaluation. Maintain this loading for 30 minutes.

   b. Perform leakage test upon completion of vibration test.

3. Acceleration Test - Place the radiator panel on test fixture for acceleration application along the major lateral axis in both directions and for application of acceleration along the longitudinal axis (flight axis) in the flight direction. Fill radiator panel with ethylene-glycol water solution and pressurize to 150±5 psig:

   a. Apply acceleration of 25g for 10±1 minutes along each axis.

   b. Perform leakage test upon completion of acceleration test.

[redacted]

[redacted]

4. Acoustical Vibration Test - Place radiator panel on test fixture to apply acoustical vibration. Fill radiator panel with ethylene-glycol water solution and pressurize to 150±5 psig:

    a. Acoustical vibration evaluation to be performed simultaneous with S/M shell acoustic test

    b. Perform leakage test upon completion of the acoustical vibration test.

5. Salt Spray Test - With a specified coating on the radiator panel, test per MIL-STD-810, Method 509.

6. Humidity Test - With a specified coating on the radiator panel, test per MIL-STD-810, Method 507.

5.3.2.4.1.3 Performance Test. The following test will be performed in a space chamber to simulate the actual conditions under which the radiator will be required to operate. The simulation of thermal loads will be achieved by adjusting the ethylene-glycol inlet temperatures and flow rates. The simulation of environmental conditions will be achieved by the use of a cold wall, infrared heat source, solar simulator, and space chamber.

1. Simulate earth orbit with X-axis tangent to trajectory. Heat inputs will be simulated by means of an infrared heat source.

    a. Place the radiator in the vacuum chamber. Decrease the chamber pressure to 10^{-5} Torr while lowering the cold-wall temperature to -320 F. For thermocouple location, see Figures 5-6 and 5-7.

    b. Start ethylene-glycol water circulating pump and supply coolant to the radiator inlet at 97.3 F and 100 lb/hr. These values are to be held constant during this phase of testing. Allow sufficient time for all readings to remain constant.

    c. Supply heat to the radiator as indicated in Table 5-1. Heat is to be applied as shown in Figure 5-8. Change the environmental incident radiation at times indicated.

    d. All data, including magnitude of environmental incident radiation, cold-wall temperature, radiator temperatures, and pressure drops, will be continuously recorded as a function of time.

    e. With the same setup, repeat the procedure, but vary the environmental incident radiation as indicated in Table 5-2.

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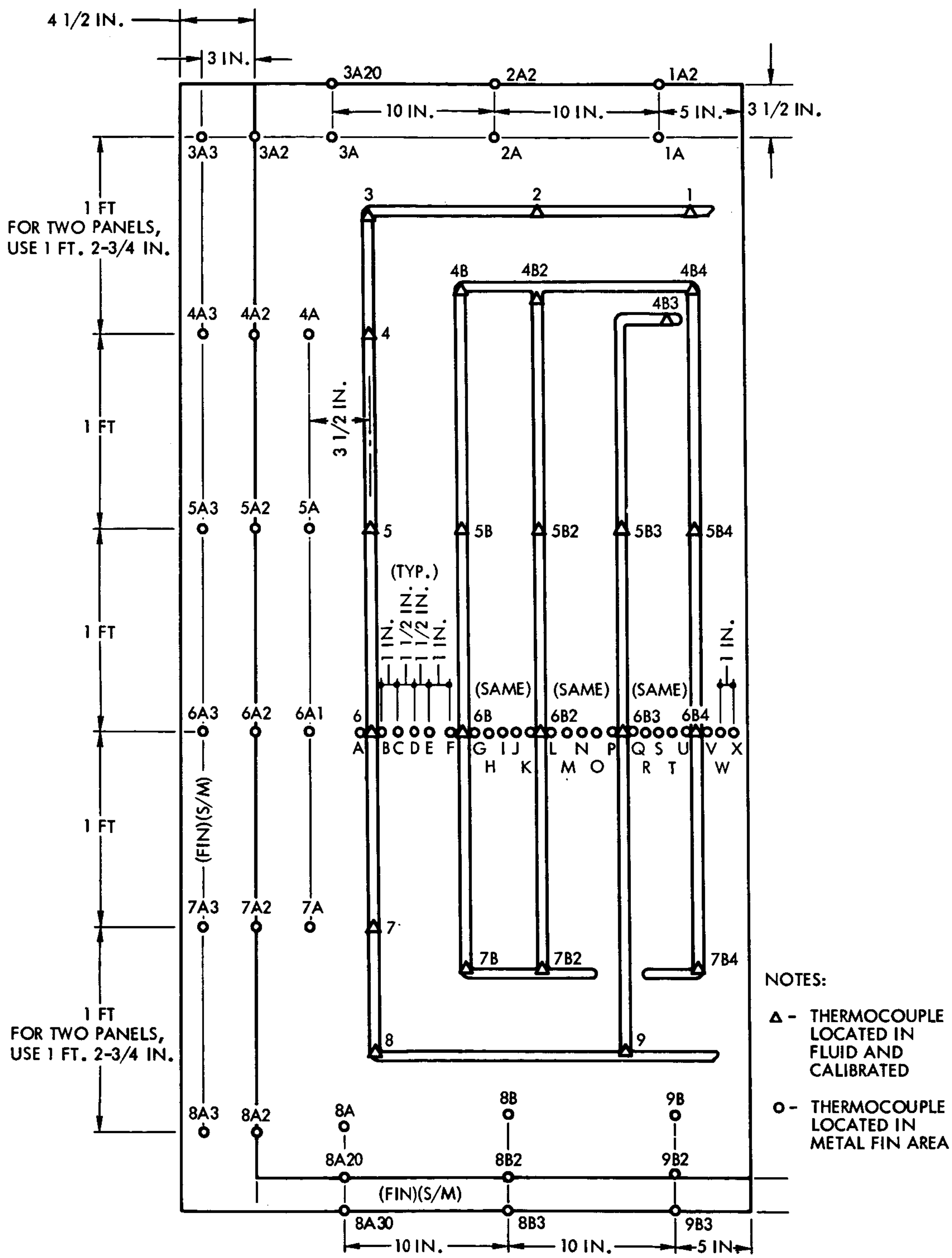

Figure 5-6. Thermocouple Location (ECS)

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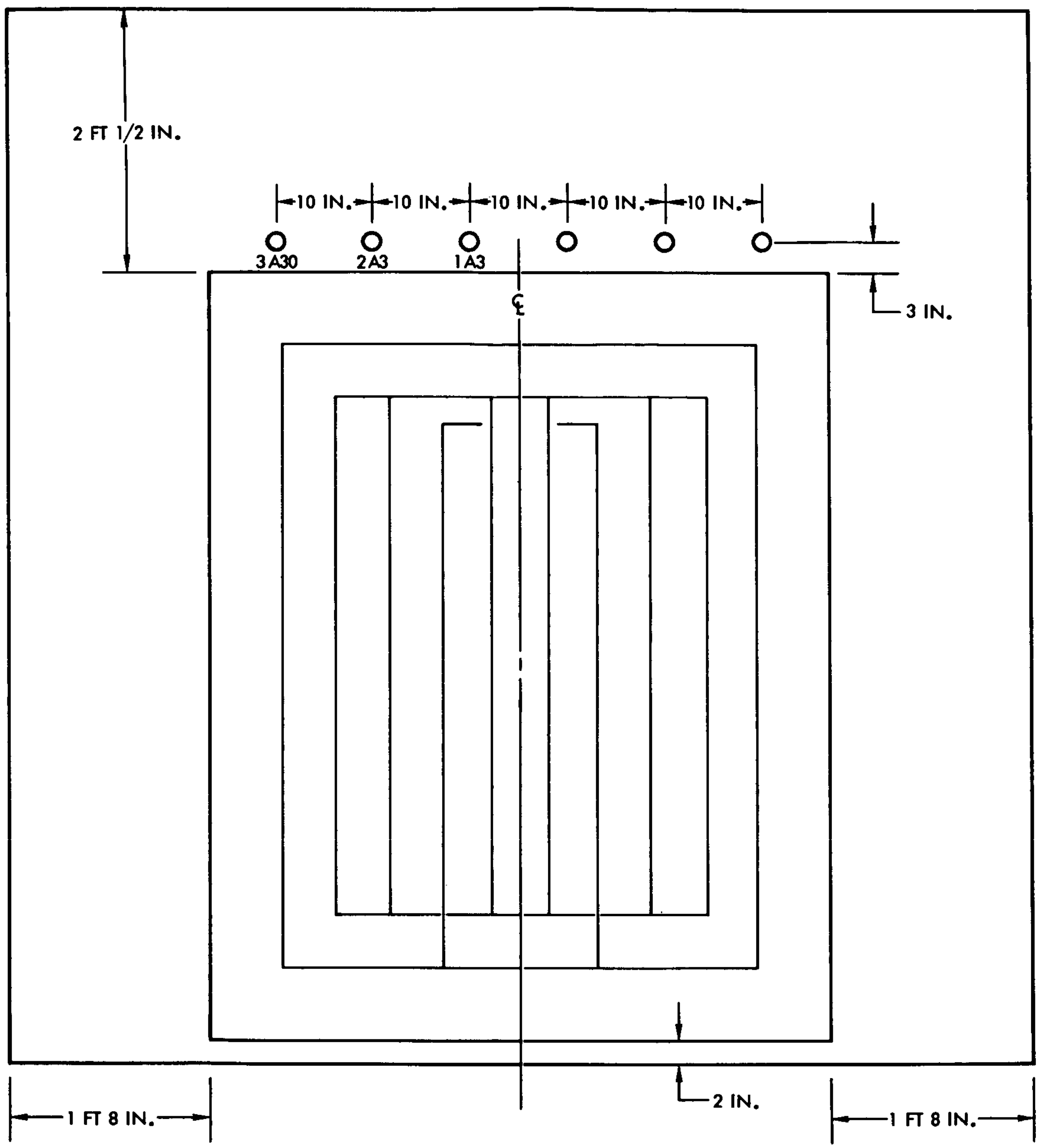

Figure 5-7. Thermocouple Edge Location on Service Module (ECS)

[redacted] [redacted]

Table 5-1. Incident IR Radiation With X-Axis Parallel to Earth Surface

RADIATOR NO. 1

Orbit Time (Degrees)	Test Time (Minutes)	IR Radiation ($Btu/Hr/Ft^2$)		
		Section A	Section B	Section C
*0	0-5	1	10	26
20	5-10	1	10	26
40	10-15	1	10	31
60	15-20	20	23	33
80	20-25	223	35	36
100	25-30	322	45	38
120	30-35	335	51	40
140	35-40	404	53	40
160	40-45	376	50	40
180	45-50	306	43	38
200	50-55	201	33	36
220	55-60	74	20	33
240	60-65	1	10	36
260	65-70	1	10	26
280	70-75	1	10	26
300	75-80	1	10	26
320	80-85	1	10	26
340	85-90	1	10	26

Note: When thermocouples 100 and 4B3 show no temperature difference, or when the temperature at 4B3 is greater than at 100, stop flow in the panel by closing the control valves and continue with test. When temperature at 4B3 becomes less than 100, reopen control valves and continue with test.

When thermocouple 200 reads less than -20 F, shut off primary circuit and continue with test. When temperature returns to above -20 F, reopen primary circuit and continue with test.

*Zero-time starts at midpoint of dark-side lunar orbit operation.

[redacted] [redacted]

[redacted]

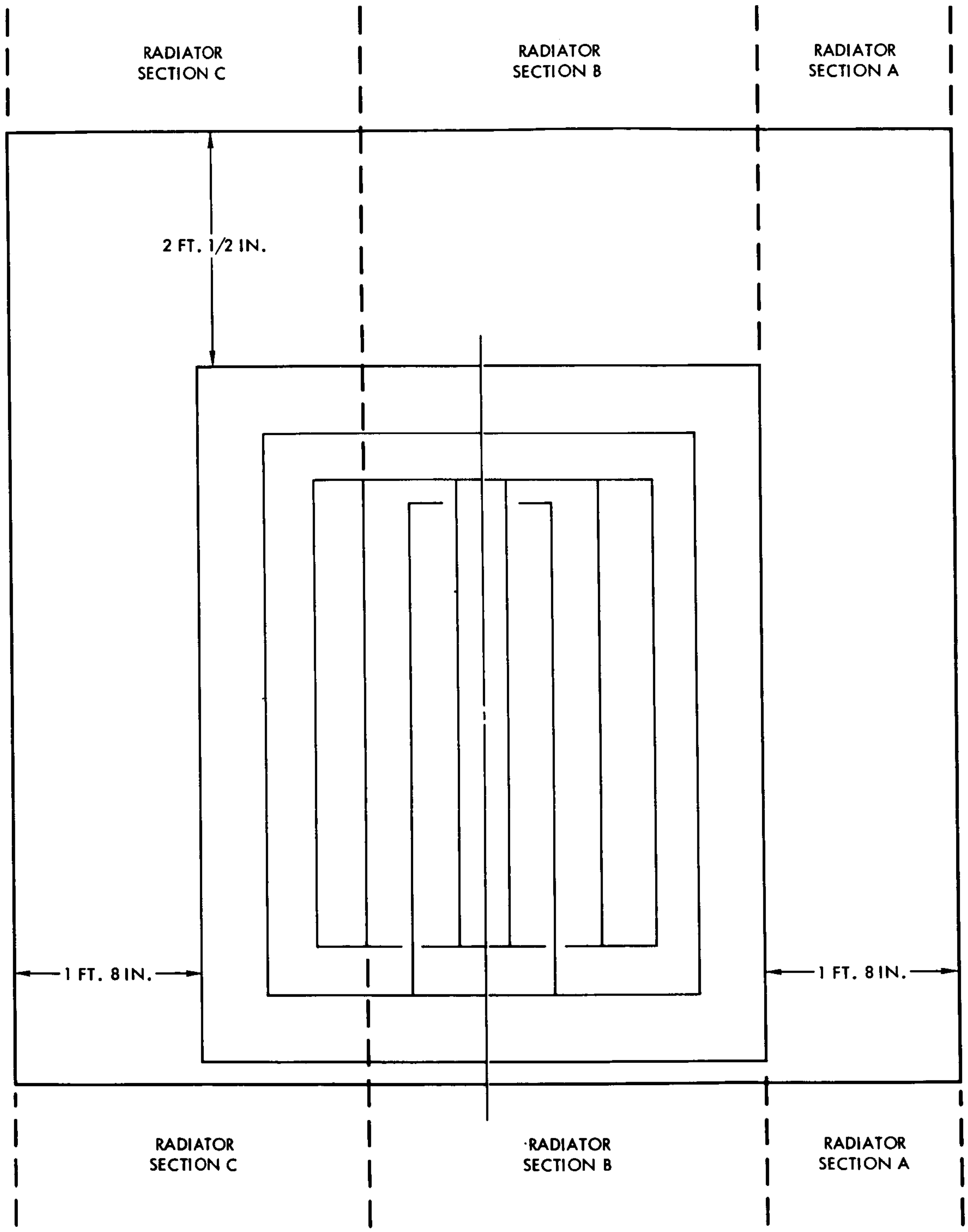

Figure 5-8. Heat Application Areas (ECS)

Table 5-2. Incident IR Radiation With X-Axis Parallel to Earth Surface

RADIATOR NO. 2

Orbit Time (Degrees)	Test Time (Minutes)	IR Radiation (Btu/Hr/Ft^2)		
		Section A	Section B	Section C
*0	0-5	60	44	26
20	5-10	60	44	26
40	10-15	60	44	26
60	15-20	87	47	28
80	20-25	129	52	30
100	25-30	162	56	33
120	30-35	184	58	34
140	35-40	190	59	35
160	40-45	181	58	34
180	45-50	157	55	32
200	50-55	121	51	30
220	55-60	79	46	27
240	60-65	121	46	27
260	65-70	60	44	26
280	70-75	60	44	26
300	75-80	60	44	26
320	80-85	60	44	26
340	85-90	60	44	26

Note: When thermocouples 100 and 4B3 show no temperature difference or when the temperature at 4B3 is greater than at 100, stop flow in the panel by closing the control valves and continue with test. When temperature at 4B3 becomes less than at 100, reopen control valves and continue with test.

When thermocouple 200 reads less than -20 F, shut off primary circuit and continue with test. When temperature returns to above -20 F, reopen primary circuit and continue with test.

*Zero-time starts at midpoint of dark-side lunar orbit operation.

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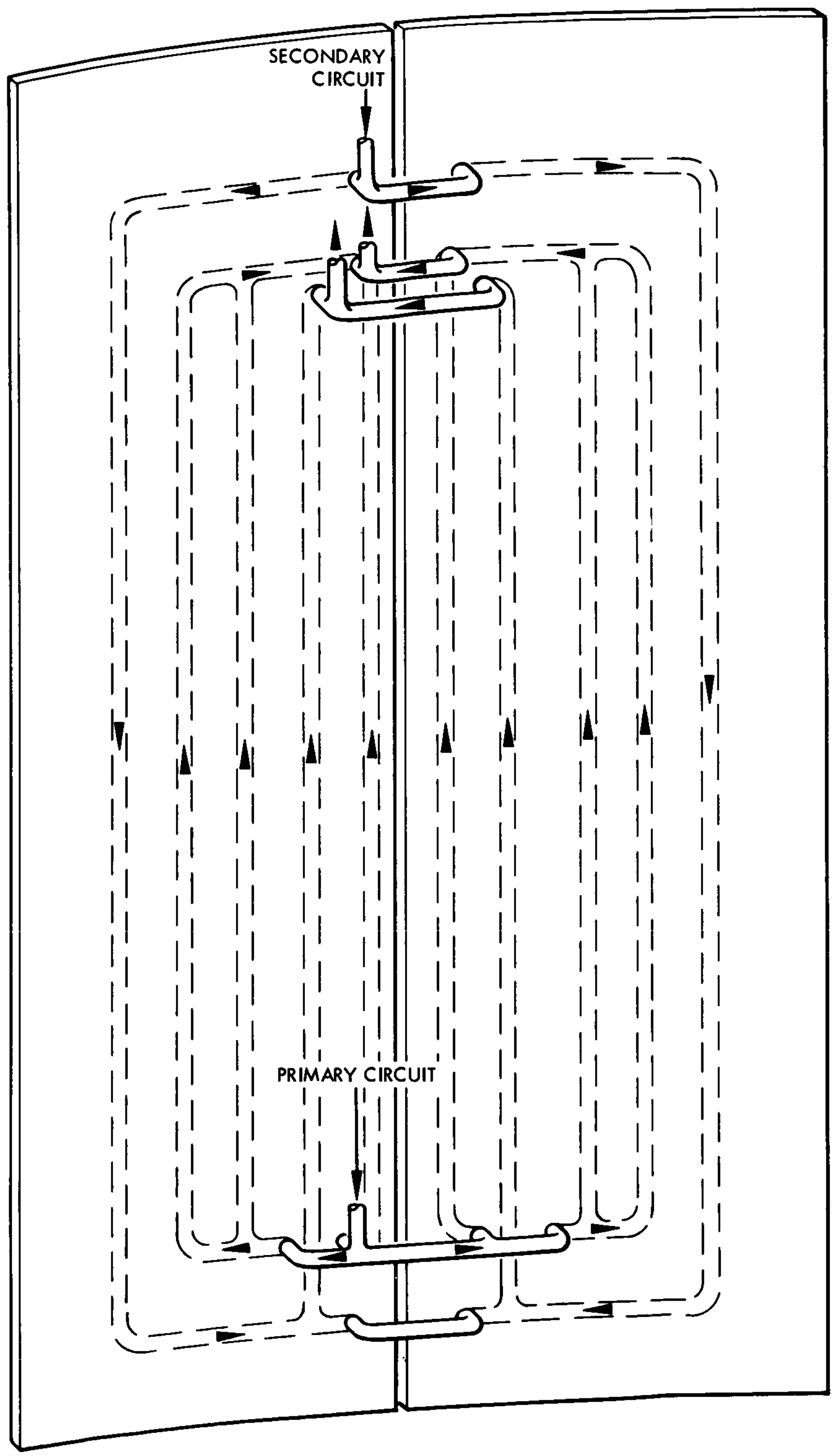


Figure 5-9. Fluid Flow Diagram: 60-sq ft Radiator (LOM)

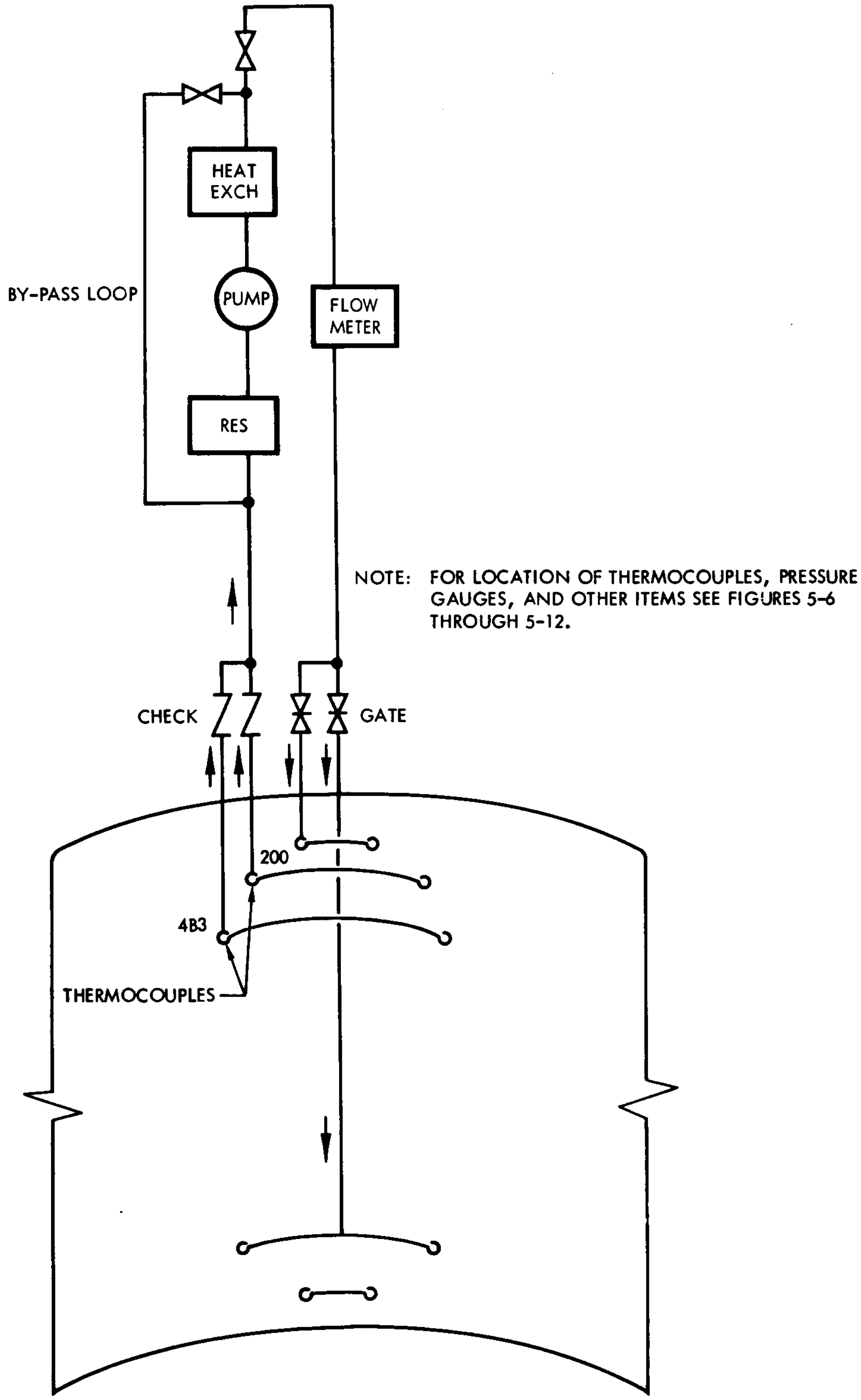


Figure 5-10. Test Setup

[redacted]

f. Record all data as in (d).

2. Simulate translunar coast. This test will consist of three parts:

a. A full radiator will be utilized with all circuits open. No solar radiation will be applied. (See Figure 5-9.)

(1) Place the radiator in the vacuum chamber. Decrease the chamber pressure to 10^{-5} Torr while lowering the cold-wall temperature to -320 F. For test setup and thermocouple location see Figures 5-6 and 5-10.

(2) Start water-glycol circulating pump and supply coolant to the panels at 200 lb/hr and an inlet temperature of 70 F.

(3) Allow sufficient time for stabilization (record readings every 15 minutes), then record temperatures, flow rate, pressures, and ΔP across panels as indicated in paragraph 5.3.2.9.4.

(4) Measure liquid ΔT across the radiator and calculate the heat rejection rate. Measure radiator metal temperature and calculate the heat rejection rate.

(5) Using the chamber environment in (1), perform tasks in (4) for each condition listed in Table 5-3.

b. The same full radiator will be utilized with only the secondary circuits open. No solar radiation will be applied. For test setup and thermocouple location, see Figures 5-9 and 5-10.

(1) With the radiator in the vacuum chamber, decrease the chamber pressure to 10^{-5} Torr while lowering the cold-wall temperature to -320 F.

(2) Start water-glycol circulating pump and supply coolant to the panels at 50.0 lb/hr and under an inlet temperature of 81.8 F.

(3) Allow sufficient time for stabilization (record readings every 15 minutes), then record temperatures, flow rate, pressure, and ΔP across the panels as indicated in paragraph 5.3.2.9.4.

[redacted]

(4) Measure liquid ΔT across the radiator and calculate the heat rejection rate. Measure radiator metal temperature and calculate the heat rejection rate.

(5) Using the chamber environment in (1), perform tasks in (3) and (4) for each of the conditions listed in Table 5-4.

Table 5-3. Test Conditions for Simulated Translunar Coast

Run No.	Coolant Flow Rate (Lb/Hr/ Radiator)	Coolant Inlet Temperature (°F)	Simulated Environmental Conditions		
			Cold Wall (°F)	Solar Simulator ($Btu/Hr/Ft^2$)	Infrared Source ($Btu/Hr/Ft^2$)
1	*20.0	70.0	-320	0.0	0.0
2	*40.0	74.5	-320	0.0	0.0
3	50.0	74.5	-320	0.0	0.0
4	80.0	74.5	-320	0.0	0.0
5	100.0	74.5	-320	0.0	0.0
6	100.0	81.8	-320	0.0	0.0
7	80.0	81.8	-320	0.0	0.0
8	50.0	81.8	-320	0.0	0.0
9	40.0	81.8	-320	0.0	0.0

*Coolant may "freeze" in duct, i.e., pressure drop across duct may exceed 10 psia. If this happens, record all data and proceed to next run.

[redacted]

Table 5-4. Test Conditions for Simulated (Secondary Circuit Operation) Translunar Coast

Run No.	Coolant Flow Rate (Lb/Hr)	Coolant Inlet Temperature (°F)	Simulated Environmental Conditions		
			Cold Wall (°F)	Solar Simulator (Btu/Hr/Ft^2 Irrad)	Infrared Source (Btu/Hr/Ft^2 Irrad)
10	18.0	81.8	-320	0.0	0.0
11	25.0	81.8	-320	0.0	0.0
12	50.0	81.8	-320	0.0	0.0
13	50.0	74.5	-320	0.0	0.0
14	25.0	74.5	-320	0.0	0.0
15	18.0	74.5	-320	0.0	0.0
16	10.0	70.0	-320	0.0	0.0
17	6.0	70.0	-320	0.0	0.0

[redacted] [redacted]

c. An abbreviated radiator, facing directly toward a solar simulator, will be used for this part. For test setup and thermocouple location, see Figures 5-10 and 5-11.

(1) With the radiator in the vacuum chamber, decrease the chamber pressure to 10^{-5} Torr while lowering the cold-wall temperature to -320 F.

(2) Start water-glycol circulating pump and supply coolant to the panel at 60 lb/hr and under an inlet temperature of 81.6 F.

(3) Allow sufficient time for stabilization, then record all temperatures, flow rate, pressures, and ΔP across the panels as in paragraph 5.3.2.9.4.

(4) Using the chamber environment in (1), subject radiator to conditions listed in Table 5-5 and record all data.

3. Simulate lunar orbit. This test will consist of two radiator orientations. (See Figure 5-12 for radiator orientation and numbering.) Heat input will be provided by an infrared heat source.

This portion of testing might be coordinated with the earth-orbit portion to eliminate additional setups.

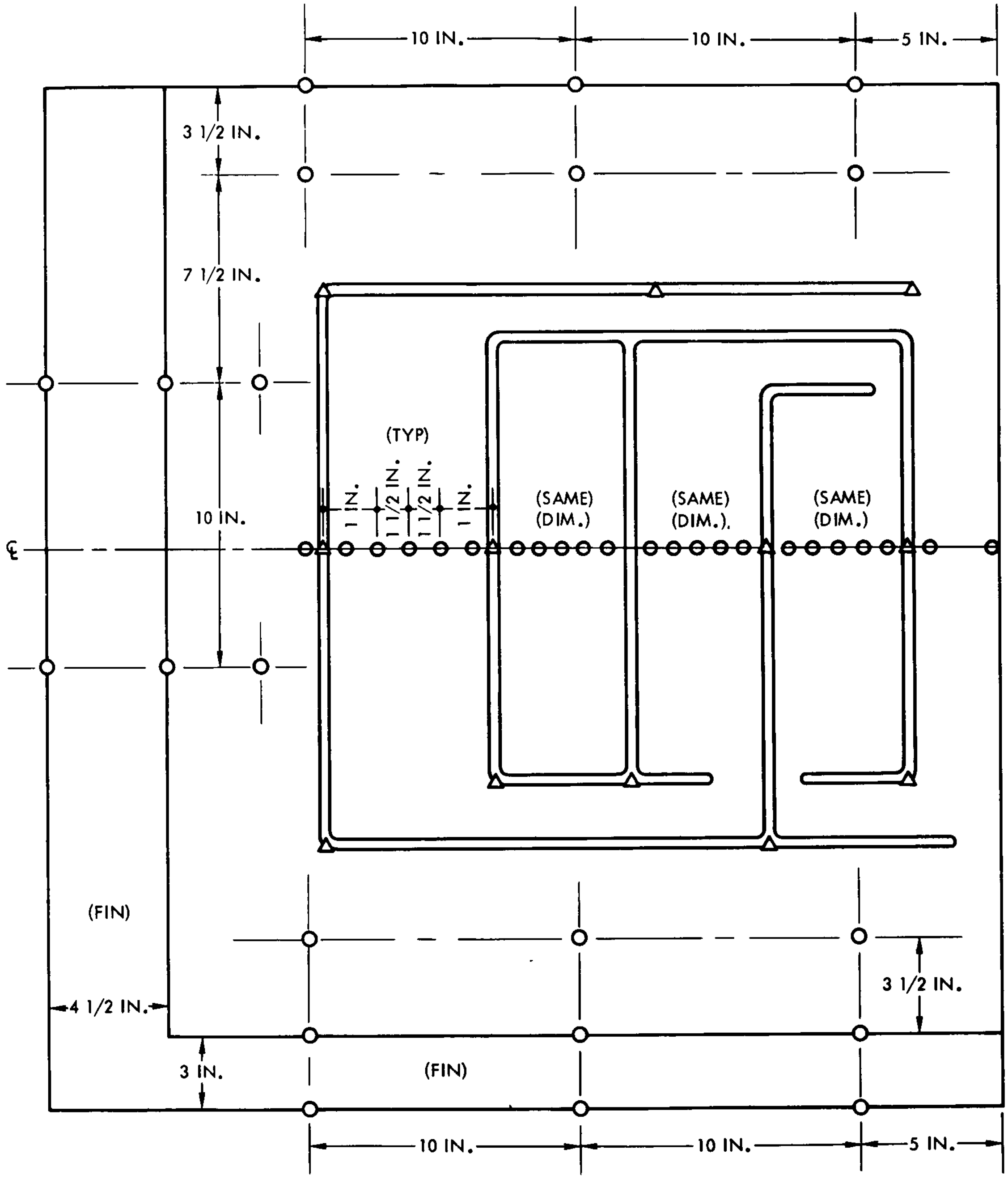
a. Orientation 1—The X-axis of radiator number 2 is perpendicular to the lunar surface.

(1) Place the radiator in the vacuum chamber. Decrease the chamber pressure to 10^{-5} Torr while lowering the cold-wall temperature to -320 F. For thermocouple location, see Figures 5-6 and 5-7.

(2) Start ethylene-glycol water circulating pump and supply coolant to the radiator inlet at 200 lb/hr and under an inlet temperature of 81.8 F. These values are to be held constant during this phase. Allow sufficient time for all readings to remain constant.

[redacted]

[redacted] [redacted]



SYMBOLS:
△ - CALIBRATED & LOCATED IN FLUID
O - LOCATED IN METAL

Figure 5-11. Solar Simulator Test Thermocouple Location

[redacted]

Table 5-5. Test Conditions for Simulated Operation of Panel Facing Sun

Run No.	Coolant Inlet Temperature (°F)	Angle of Panel (Degrees)	Coolant Flow Rate (Lb/Hr)	Simulated Environmental Conditions		
				Cold Wall (°F)	Solar Simulator Output ($Btu/Hr/Ft^2$) (2 Suns)	Infrared Source Output ($Btu/Hr/Ft^2$)
18	74.5	-90	120	-320	886	0
19	74.5	-90	120	-320	886	0
20	74.5	-30	120	-320	886	0
21	74.5	0	120	-320	886	0
22	74.5	±30	120	-320	886	0
23	74.5	+60	120	-320	886	0
24	74.5	+90	120	-320	886	0
25	81.6	+90	120	-320	886	0
26	81.6	+60	120	-320	886	0
27	81.6	+30	120	-320	886	0
28	81.6	0	120	-320	886	0
29	81.6	-30	120	-320	886	0
30	81.6	-60	120	-320	886	0
31	81.6	-90	120	-320	886	0

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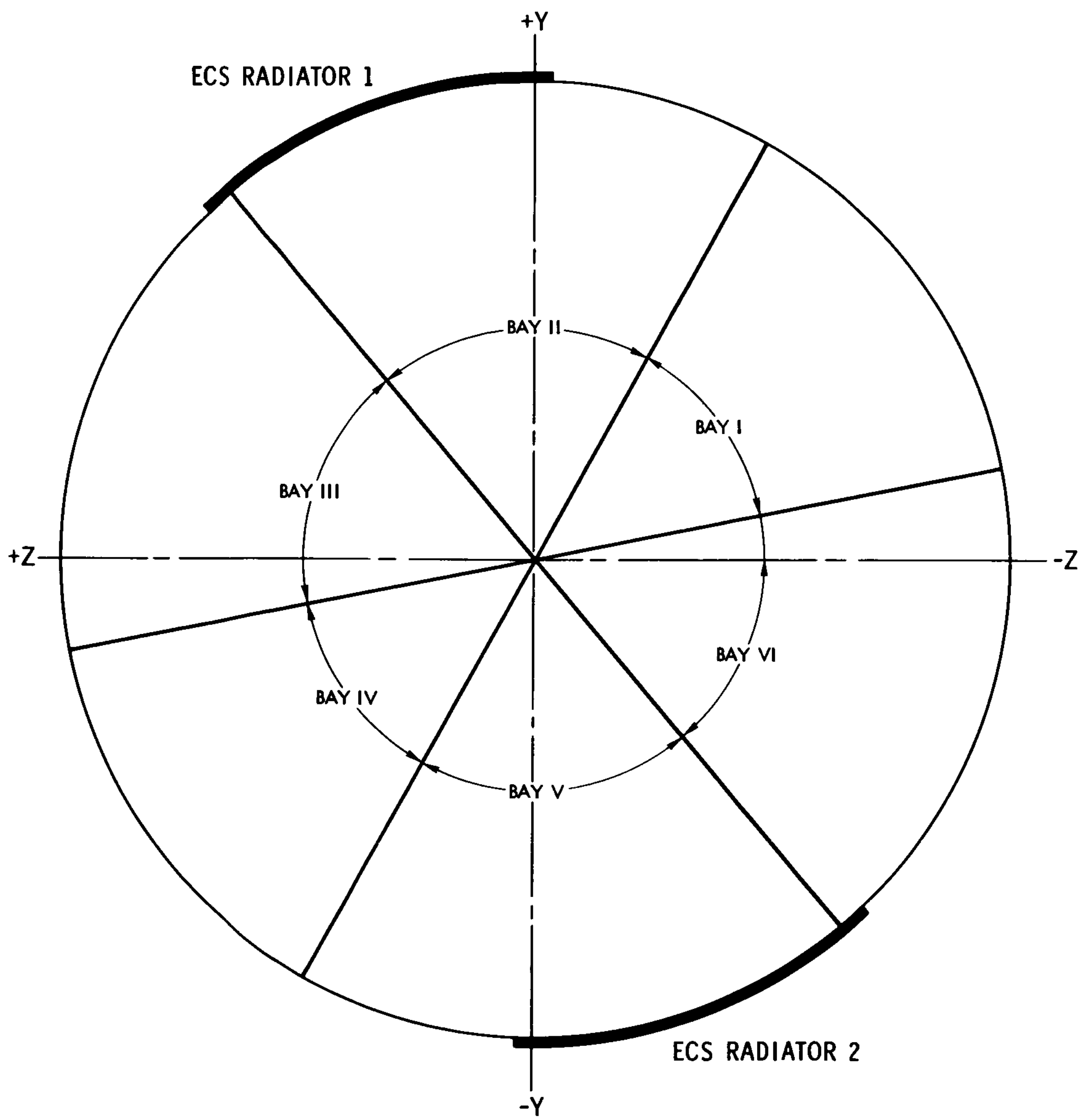

Figure 5-12. ECS Radiator Location

[redacted]

(3) Supply heat to the radiator as indicated in Table 5-6. Heat is to be applied as shown in Figure 5-8. Change the environmental incident radiation at times indicated regardless of the flow rate through the panel. Refer to note on Table 5-6.

(4) All data, including magnitude of environmental incident radiation, cold-wall temperature, radiator temperature, and pressure drops, will be continuously recorded as a function of time. Record the time at which any temperature, flow rate, or circuit switch has been changed from the normal operational mode. When any circuit has been switched off, do not vent it.

b. Orientation 1 (Deviated)—With the X-axis of radiator number 2 parallel to the lunar surface, repeat conditions in (a.1) through (a.4), but use Table 5-7 for environmental incident radiation application.

(Note: Under actual system operation, the full radiator system flow rate of 200 lb/hr is diverted into one radiator when the other radiator is switched off. Thus, in this run it will be necessary to flow 200 lb/hr at the time in orbit that radiator number 2 is completely switched off.)

c. Orientation 2—With the X-axis of radiator number 1 perpendicular to the lunar surface, proceed as in (a.1) through (a.4), but use Table 5-8 for environmental incident radiation. (See note above.)

d. Orientation 2 (Deviated)—With the X-axis of radiator number 1 parallel to the lunar surface, repeat conditions in (a.1) through (a.4), but use Table 5-9 for environmental incident radiation application.

5.3.2.4.1.4 Radiator Temperature Control Coatings Tests. Candidate coatings will be selected that exhibit promising optical and temperature control properties when evaluated against the major components of the space environment. Identical specimens coated with the selected materials will be subjected to the following screening tests.

1. Determine the emissivity and solar absorptivity of each candidate material using a total normal thermal emittance apparatus.

[redacted]

Table 5-6. Incident IR Radiation With X-Axis Perpendicular to Lunar Surface

RADIATOR NO. 2				
Orbit Time (Degrees)	Test Time (Minutes)	IR Radiation (Btu/Hr/Ft^2)		
		Section A	Section B	Section C
*0	0-7	1	1	1
20	7-14	1	1	1
40	14-21	1	1	1
60	21-28	1	1	1
80	28-35	1	36	1
100	35-42	22	54	20
120	42-49	60	84	54
140	49-56	91	105	82
160	56-63	111	112	100
180	63-70	118	107	107
200	70-77	242	101	101
220	77-84	337	82	82
240	84-91	392	54	54
260	91-98	399	20	20
280	98-105	379	1	1
300	105-112	1	1	1
320	112-119	1	1	1
340	119-126	1	1	1

Note: When thermocouples 100 and 4B3 show no temperature difference, or when the temperature at 4B3 is greater than at 100, stop flow in the panel by closing the control valves and continue with test. When temperature at 4B3 becomes less than at 100, reopen valves and continue with test.

When thermocouple 200 reads less than -20 F, shut off primary circuit and continue with test. When temperature returns to above -20 F, reopen primary circuit and continue with test.

*Zero-time starts at midpoint of dark-side lunar orbit operation.

[redacted]

Table 5-7. Incident IR Radiation X-Axis Parallel to Lunar Surface

RADIATOR NO. 2				
Orbit Time (Degrees)	Test Time (Minutes)	IR Radiation (Btu/Hr/Ft^2)		
		Section A	Section B	Section C
*0	0-7	4	2	1
20	7-14	4	2	1
40	14-21	4	2	1
60	21-28	4	2	1
80	28-35	70	8	1
100	35-42	64	39	20
120	42-49	178	108	54
140	49-56	271	165	82
160	56-63	353	201	101
180	63-70	353	214	107
200	70-77	332	201	101
220	77-84	271	165	82
240	84-91	178	108	54
260	91-98	64	39	20
280	98-105	70	8	1
300	105-112	4	2	1
320	112-119	4	2	1
340	119-126	4	2	1

Note: When thermocouples 100 and 4B3 show no temperature difference, or when the temperature at 4B3 is greater than at 100, stop flow in the panel by closing the control valves and continue with test. When temperature at 4B3 becomes less than at 100, reopen control valves and continue with test.

When thermocouple 200 reads less than -20 F, shut off primary circuit and continue with test. When temperature returns to above -20 F, reopen primary circuit and continue with test.

*Zero-time starts at midpoint of dark-side lunar orbit operation.

[redacted]

Table 5-8. Incident IR Radiation X-Axis Perpendicular to Lunar Surface

RADIATOR NO. 1				
Orbit Time (Degrees)	Test Time (Minutes)	IR Radiation (Btu/Hr/Ft^2)		
		Section A	Section B	Section C
*0	0-7	1	1	1
20	7-14	1	1	1
40	14-21	1	1	1
60	21-28	1	1	1
80	28-35	379	1	1
100	35-42	399	20	20
120	42-49	392	54	54
140	49-56	337	82	82
160	56-63	242	101	101
180	63-70	118	107	107
200	70-77	111	112	101
220	77-84	91	105	82
240	84-91	60	84	54
260	91-98	22	54	20
280	98-105	1	36	1
300	105-112	1	1	1
320	112-119	1	1	1
340	119-126	1	1	1

Note: When thermocouples 100 and 4B3 show no temperature difference, or when the temperature at 4B3 is greater than at 100, stop flow in the panel by closing the control valves and continue with test. When temperature at 4B3 becomes less than at 100, reopen control valves and continue with test.'

When thermocouple 200 reads less than -20 F, shut off primary circuit and continue with test. When temperature returns to above -20 F, reopen primary circuit and continue with test.

*Zero-time starts at midpoint of dark-side lunar orbit operation.

[redacted]

Table 5-9. Incident IR Radiation X-Axis Parallel to Lunar Surface

RADIATOR NO. 1				
Orbit Time (Degrees)	Test Time (Minutes)	IR Radiation (Btu/Hr/Ft^2)		
		Section A	Section B	Section C
*0	0-7	0	0.3	1
20	7-14	0	0.3	1
40	14-21	0	0.3	1
60	21-28	0	0.3	1
80	28-35	0	0.3	1
100	35-42	67	11	20
120	42-49	192	32	54
140	49-56	294	49	82
160	56-63	360	60	101
180	63-70	384	64	107
200	70-77	360	60	101
220	77-84	294	49	82
240	84-91	192	32	54
260	91-98	97	11	20
280	98-105	0	0.3	1
300	105-112	0	0.3	1
320	112-119	0	0.3	1
340	119-126	0	0.3	1

*Zero-time starts at midpoint of dark-side lunar orbit operation.

[redacted]

Two panels, 2 in. x 2 in. x 0.32 in., of each material shall be tested. Properties shall be determined at 500 F, 225 F, and one lower temperature, if possible, while at atmospheric pressure.

2. Expose two panels, 7/8-in. diameter x 0.032 in., of each coating to a vacuum of from 10^{-7} to 10^{-10} mm Hg, for a minimum of 48 hours. Weight loss due to sublimation, outgassing, or other degradation shall be measured.

3. Expose two panels, 7/8-in. diameter x 0.32 in., of each coating to ultraviolet radiation (one solar) for a minimum of 48 hours at atmospheric pressures. Any appreciable color changes shall be cause for rejection.

After screening each coating against the major individual components of the space environment, each set of coated specimens will be tested under the following major environments, consecutively. A minimum of two test specimens of each coating, 7/8-in. diameter x 0.032 in., will be used. Only materials that have passed the screening tests will be evaluated.

1. Each specimen will be submitted to a postlaunch environmental test to determine the effect of heat and vacuum on coatings that will be encountered during the ascent phase, just after launching. The coatings will be exposed to approximately 600 F for 30 to 60 seconds at a constant pressure of 10 mm Hg. The test will be repeated at a constant pressure of 10^{-3} mm Hg. Total normal emittance will be determined before and after this test. These properties will be determined at 225 F. Coatings that prove unsatisfactory will not be further tested.

2. Each specimen will be exposed to a vacuum of 10^{-8} mm Hg minimum for 500 hours. Loss of weight and the radiative properties of each coating will be determined before and after the test.

3. Each specimen will be exposed to ultraviolet radiation (one solar) for 500 hours. Visual examination and radiative properties will be determined before and after the test.

[redacted]

4. Each specimen will be exposed to a combination of high vacuum (10^{-8} mm Hg) ultraviolet radiation (one sun) for 500 hours. Radiative properties will be determined before and after each test.

5. Each specimen will be subjected to a single exposure of one hour to a temperature of -420 ± 10 F. Each coating will be examined for deleterious effects, and the radiative properties will be determined before and after the exposure.

6. Each specimen will be exposed to micrometeroid impact. The specimens will be so tested as to avoid any edge effect. Each specimen will be examined to determine the degree of degradation. If the coating remains intact, the radiative properties will be determined.

7. Methods of handling and protecting radiators that have temperature coatings will be developed. A protective covering will be developed that will shield the coating from contamination during storage.

8. Deterioration of the radiative properties of a coating after storage will be determined.

9. Coatings that prove unsatisfactory during the above tests will be reformulated, if possible, to improve their performance. Coatings that cannot be improved to meet these tests will be rejected.

Coatings that appear promising after the various tests listed above have been completed will be tested as follows:

1. Two test specimens, 1-in. diameter discs, will be coated with candidate coatings and their radiative properties determined. The two specimens will then be subjected to the tests of (2) through (6) above simultaneously. Optical properties will be determined and recorded after each test.

2. Model radiators will be fabricated and tested under simulated space environments and at operational heat rejection loads. These radiators will use the coatings that prove the most satisfactory above. The results of these tests will determine the final material.

Supplementary Information.

1. Reaction control system space exhaust plume tests. Combustion products from the RCS and sublimation products from the RCS nozzle may deposit on or near the space radiator surfaces during flight. Tests to predict the amount of radiator surface

[redacted]

contamination possible, and the effect of this contamination on the radiator surface coating optical and mechanical properties, will be run in conjunction with the hot firing tests of the full scale RCS motors under near-vacuum conditions.

2. Actual space environment tests. When possible, candidate coatings will be subjected to actual space environments by placing them onboard orbiting vehicles. The frequency with which these tests are conducted will depend on the limitation existing for instrumentation space on the vehicle and test priorities. These tests will be coordinated through NASA.

3. Space vehicle contaminants test. A series of tests will investigate the effects of common space vehicle contaminants (propellant, lubricants, etc.) on the optical and mechanical properties of the candidate coatings. The necessary precautions and techniques for providing protection for the radiator surface will be developed in a parallel effort.

4. Nuclear radiation. Each coating will be exposed to nuclear radiation conforming to the NASA-supplied profile for the mission. The coatings will be examined to determine any degradation, and the radiative properties will be remeasured to determine any change in optical properties.

5.3.2.4.2 Qualification Test. The qualification test program will consist of selected tests from the design verification testing plus environmental tests, for the production prototype.

5.3.2.4.2.1 Design Verification Tests. The following represents the tests planned for qualification of design:

1. Repeat section 5.3.2.4.1.2, paragraph 1, only.

5.3.2.4.2.2 Environmental Tests. The following represents the tests planned for qualification to the Apollo environment:

1. Repeat section 5.3.2.4.1.1

2. Repeat section 5.3.2.4.1.2

5.3.2.5 Order Of Tests (Deleted)

5.3.2.6 Test Records

Radiator panels are to be assigned numbers. As the radiators are processed and tested, all data pertaining to that panel will be referenced with the number assigned. Copies of all data will be forwarded to ECS.

5.3.2.7 Failures

In the event of a malfunction, the test will be stopped, and an inspection of the test setup will be started to determine the cause. Prior to resuming testing, ECS will be notified and all data pertinent to the malfunction will be recorded. If the cause is not in the radiator panels, the malfunction can be repaired and testing resumed.

5.3.2.8 Cleanliness

All surfaces of the radiator panel will be kept clean, free of any foreign matter.

5.3.2.9 Equipment Requirements

The items listed and described below represent the major components needed for the development and qualification testing of the radiator panels. Any deviations, additions, or deletions by the testing group must have ECS approval prior to start of test.

5.3.2.9.1 Radiator Panels. Eight panels will be provided to begin the development testing. Present plans require various tests to be run simultaneously on different radiator panels at EDL or wherever test facilities are available.

The radiators will be fabricated to the design specifications described on drawings No. V17-615002 and V17-616005.

Radiator panels specified by ECS will have spacecraft aluminum foil bonded to the back by the testing group to simulate configuration requirements. Not all panels will have spacecraft covering on the back. (See drawing V17-322030 for sketch of aluminum foil backing.)

5.3.2.9.2 Solar Simulator. The solar simulator will be capable of producing an irradiation up to one sun normal to the entire test specimen surface and of varying the source strength or the view factor to the radiator surface as a function of time without significant change in the wave lengths of the radiation. It will also provide the following:

1. Incident Solar Radiation - The incident energy will be composed of the following spectral percentages and will correspond to the solar spectral distribution:

Ultraviolet	(2000 - 3800 A°)	8%±1%
Visible	(3800 - 7000 A°)	41%±3%
Infrared	(7000 - 10,000 A°)	22%±3%
For Infrared	(10,000 - 20,000 A°)	23%±2%

[redacted]

All incident radiation is to be collimated or otherwise controlled to insure parallelism of the radiation within ±1.5 percent.

2. Reflected Solar Radiation From Earth - The reflected solar radiation from the earth will be composed of the following percentages of the incident radiation:

Ultraviolet — 50 percent
Visible — 40 percent
Infrared (all wave lengths) — 30 percent

The intensity of reflected solar radiation from the earth will be 159 Btu/hr/ft^2 ±5 percent.

3. Earth Emission - The heat flux of earth emission shall be 71 Btu/hr/ft^2 ±5 percent in the infrared region.

Radiator panels will experience no significant degradation in performance resulting directly or indirectly from exposure to solar radiation; if degradation occurs, test shall be classified "Failure" and reported to ECS for action.

(Ref. Figure 5-13, Solar Simulator Test—when large chamber is available.)

5.3.2.9.3 Infrared Heat Source. The infrared heat source will be capable of producing an irradiation up to 425 Btu/hr/ft^2 specimen and of varying the source strength or the view factor to the radiator surface with minimum changes in wave length of radiation as a function of time.

5.3.2.9.4 Instrumentation and Measuring Equipment. The following instruments are required for the test program. Additional instruments may be required by ECS at a later date. All instruments and recording devices will have an accuracy of within ±1 F.

1. Thermocouples (small gauge, insulated, precision-type) with a temperature range of 100 F to -60 F will be attached to the back of the radiator test panels. (See Figures 5-6, 5-7, 5-14, and 5-15. For location of thermocouples in solar simulation test, see Figure 5-11.)

Thermocouple readings will be recorded by an automatic recording device.

Thermocouples located at the inlet and outlet of water-glycol system will measure the temperature of the fluid and not the temperature of the surface of the coupling.

[redacted]

[redacted] [redacted]

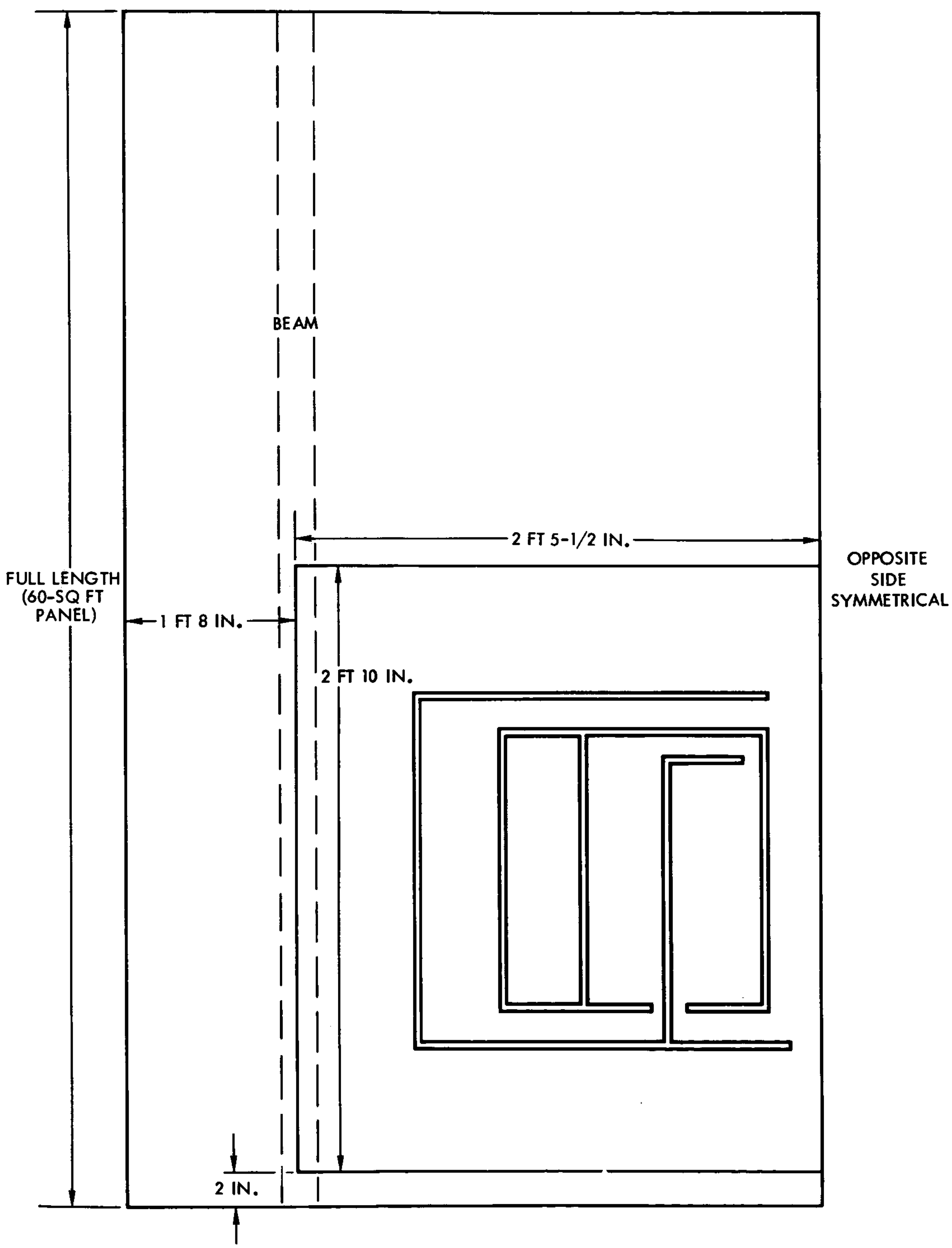

Figure 5-13. Solar Simulator Test (ECS)

[redacted] [redacted]

[redacted]

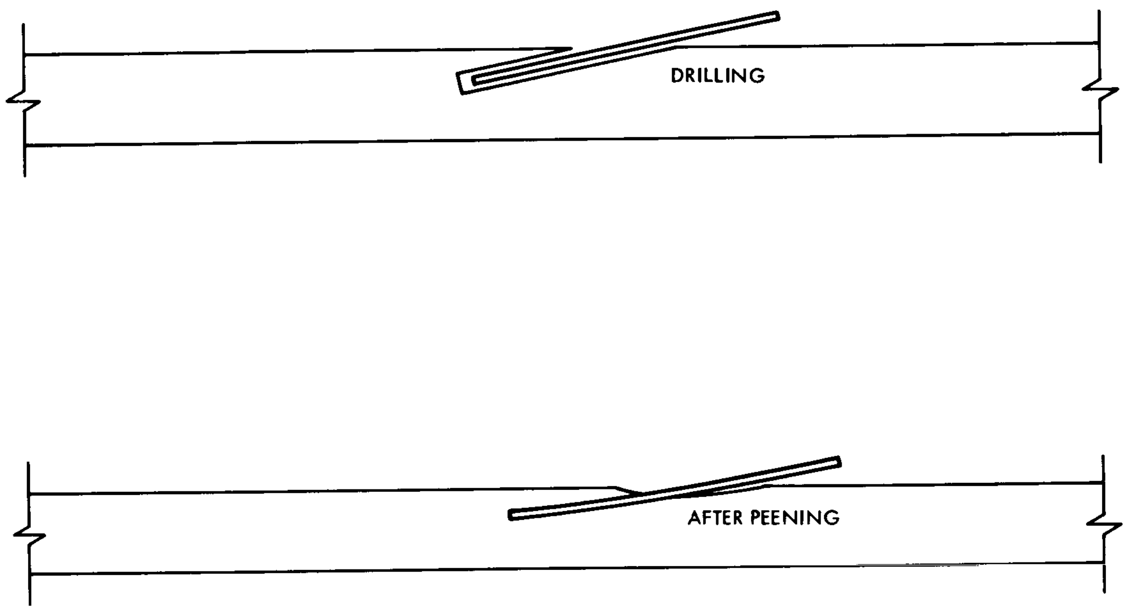

Figure 5-14. Thermocouple Attachment

[redacted]

[redacted] [redacted]

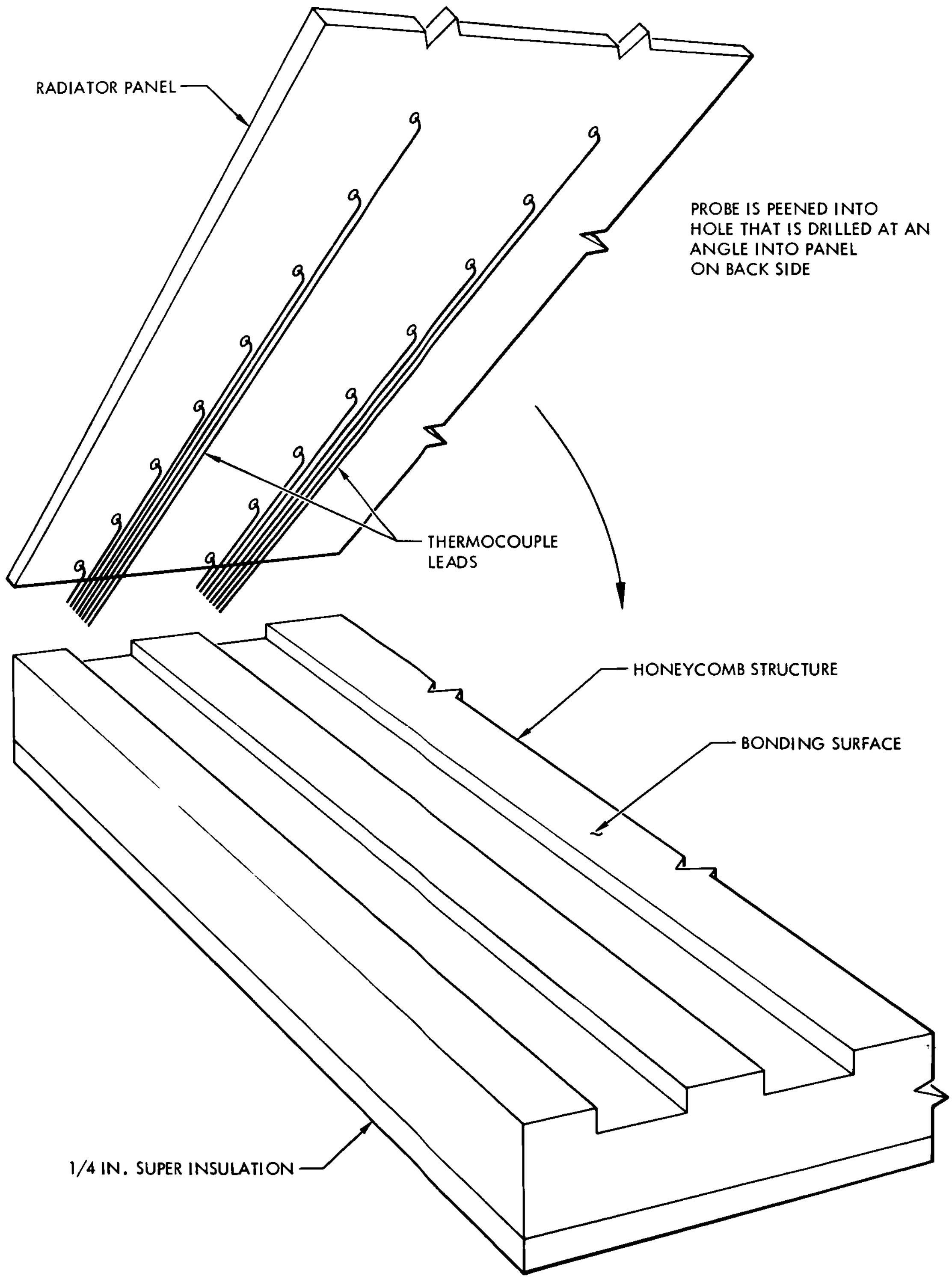

Figure 5-15. Method of Thermocouple Attachment (ECS)

[redacted]

[redacted]

Specified thermocouples will use exit temperature of primary circuit as reference to provide greater accuracy.

Specified thermocouples will be calibrated; at finish of test they will be recalibrated.

2. Differential pressure gauges will be used for readings across the radiator panels at various points as specified. (See Figure 5-10 for test setup.) Gauges will be capable of measuring pressure differentials within 0.1 psi at a maximum total pressure differential of 15 psi. (See Figure 5-16.)

3. A calibrated flowmeter will be required. Also, a backup of measuring and timing will be accomplished by catching the return liquid for a specified time. (See Figure 5-17.)

4. Portable optical measuring device—a Beckman DK-2 spectrophotometer or its equivalent.

5.3.2.10 Data Requirements

All data listed below will be recorded and the information transmitted for study by groups concerned. Any additional information not specified but which becomes available to the testing group also will be recorded.

1. Temperatures from all specified instrumented points will be continuously recorded during all phases of testing.

2. Inlet and ΔP pressures across panels are to be automatically and continuously recorded during all of the testing phases.

3. Flow rates of water-glycol are to be recorded automatically and continuously during all phases of testing.

4. Space-chamber cold-wall temperatures will be recorded automatically and continuously for various points that face the radiator panels. The emissivity of the cold wall will be recorded.

5.3.2.11 Facility Requirements

1. A space simulation chamber of sufficient capacity to hold the radiator panels. Maximum chamber pressure will be 1×10^{-5} Torr, and the chamber will have liquid nitrogen cooled walls that have been thermal coated to simulate a black body with an emissivity of 0.96. The cold wall will be maintained at -320 F for the duration of the test.

[redacted]

[redacted] [redacted]

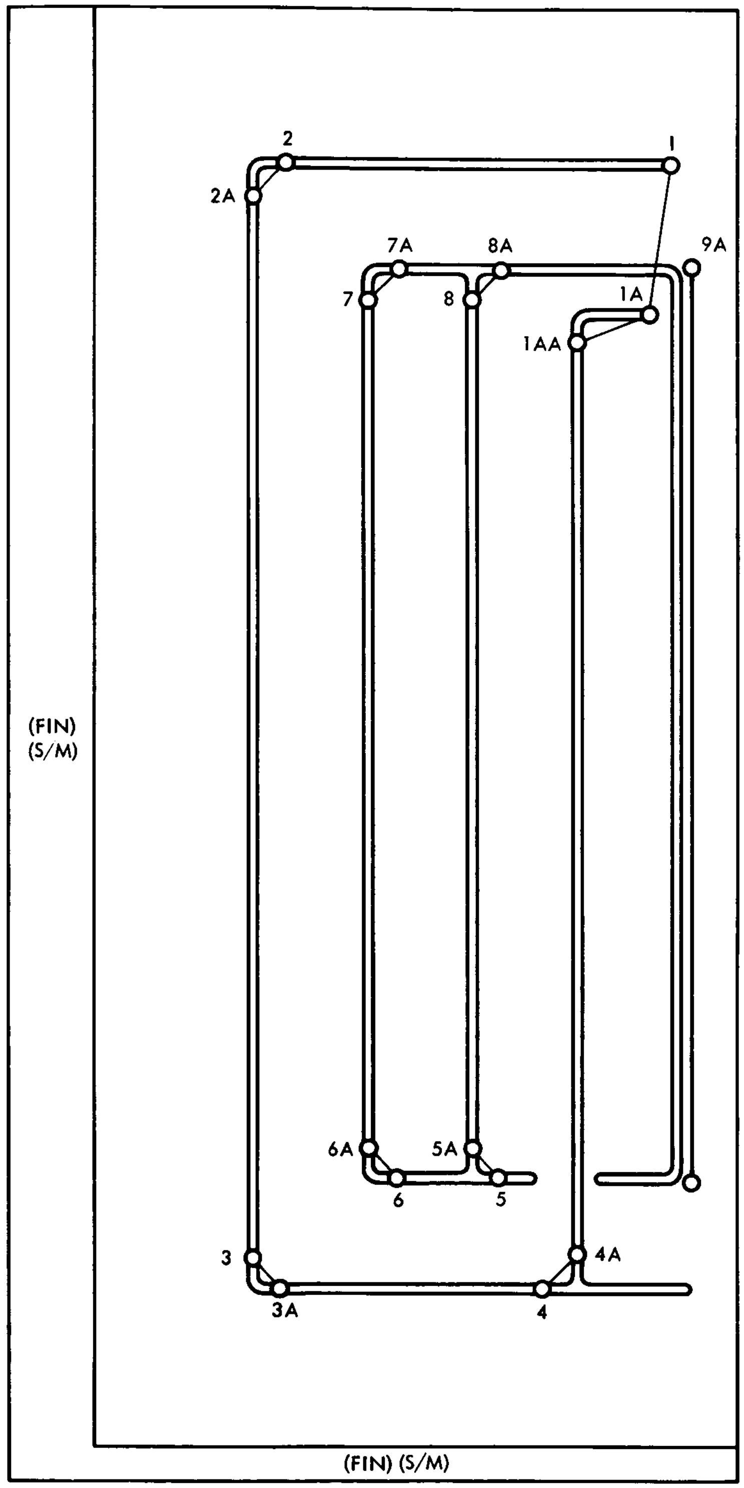

Figure 5-16. ECS Differential Pressure Gauge Location

[redacted]

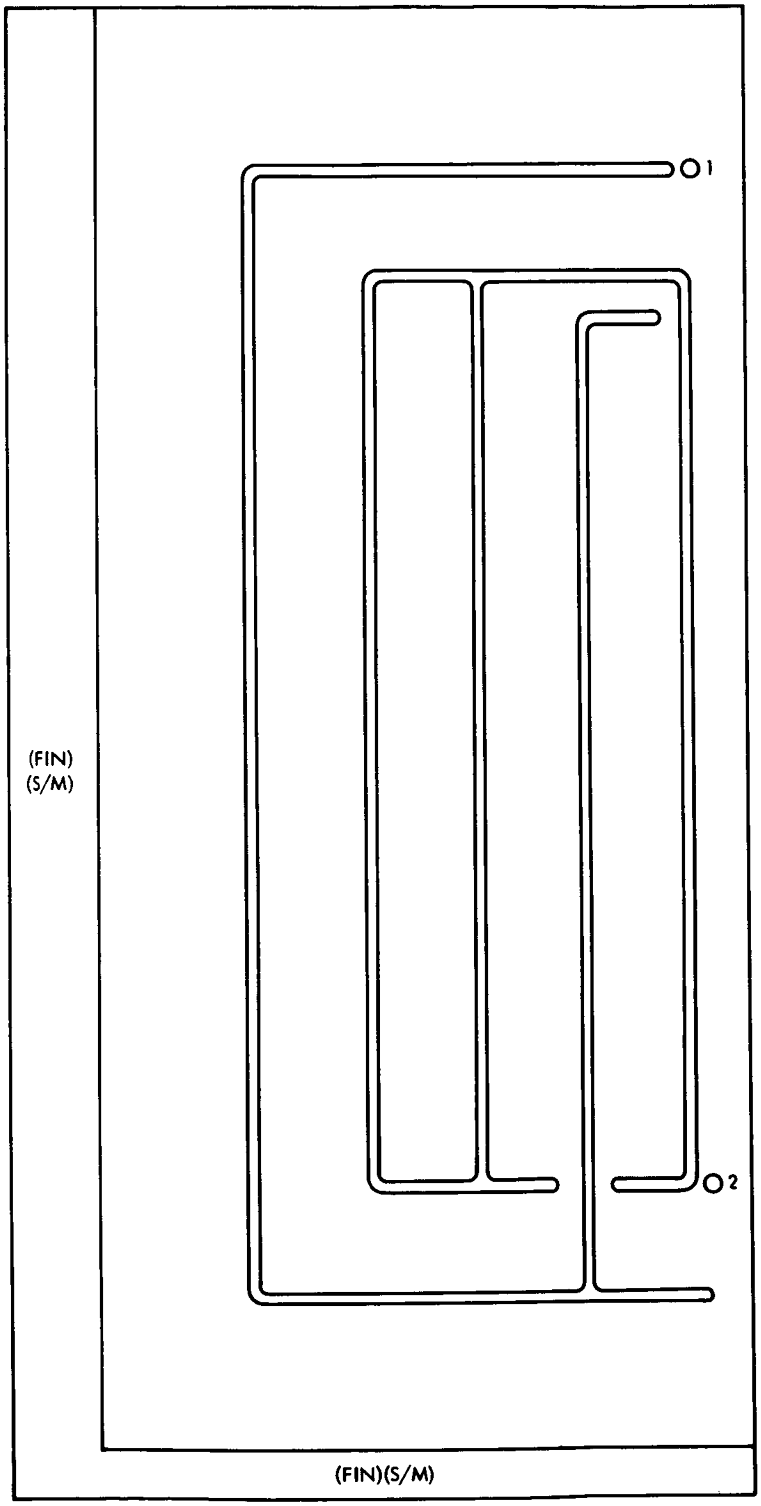

Figure 5-17. Flow Meter Locations (ECS Radiator Panel)

[redacted]

2. A circulating system (ethylene-glycol-water) including pump, heat exchangers, flow measuring device, flow control valves, pressure gauges, and differential pressure gauges. Mixture to consist of 62.5 percent ethylene-glycol and 37.5 percent distilled water. No cuprous material that would come in contact with the solution will be used in the test setup.

In addition, the system will provide constant flow rate up to 200 lb/hr, constant coolant inlet temperature in the range of 100 F to 70 F, and duct by-passing. The pump will be capable of operating against pressure head of 15 psi.

5.3.3 Coldplate Test

5.3.3.1 Test Objectives

The objectives are to evaluate and demonstrate the capability of an integrated network of coldplates to provide thermal control of the electronic equipment in the C/M under simulated mission environments and to verify that the water-glycol mixture is compatible with the material forming the network fluid passageways. The network will consist of a complete C/M coldplate system which will be verified structurally and functionally through AFRM 6 and 8, respectively. (Figure 5-18 shows the actual flight configuration flow diagram; Figure 5-19 shows a typical coldplate test system.)

A coldplate test program will be conducted by S&ID to produce coldplate units structurally strong enough to withstand the dynamic conditions during flight and to provide continuous thermal control of the electronic equipment operating in the command module throughout the Apollo mission.

5.3.3.2 Test Plan

5.3.3.2.1 Preliminary Tests

5.3.3.2.1.1 Mechanical Inspection. Each coldplate will be mechanically inspected for dimensional accuracy and surface flatness, for cleanliness, and for nonobstruction by foreign material in the passages. X-Ray inspection will be utilized where applicable.

5.3.3.2.1.2 Proof Pressure. Tests will be conducted as follows:

1. Install the coldplate in a test fixture so that a pressure of 90 psig may be applied internally to the coldplate.

2. Maintain 90 psig for 15 minutes and observe for any failures in the coldplate. If none appear, the test will be considered satisfactory and terminated.

[redacted]

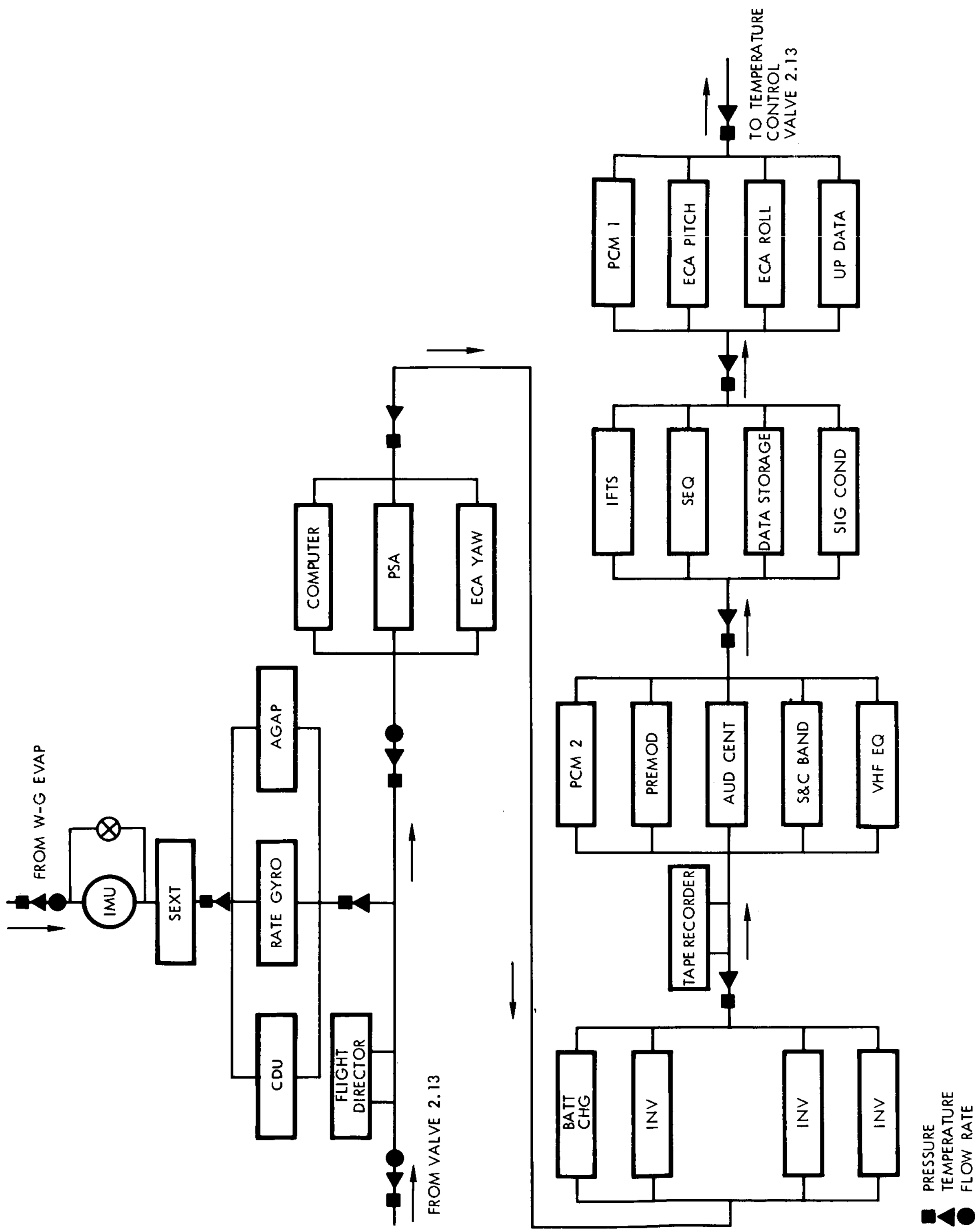

Figure 5-18. Coldplate Flow Diagram

[redacted]

[redacted] [redacted]

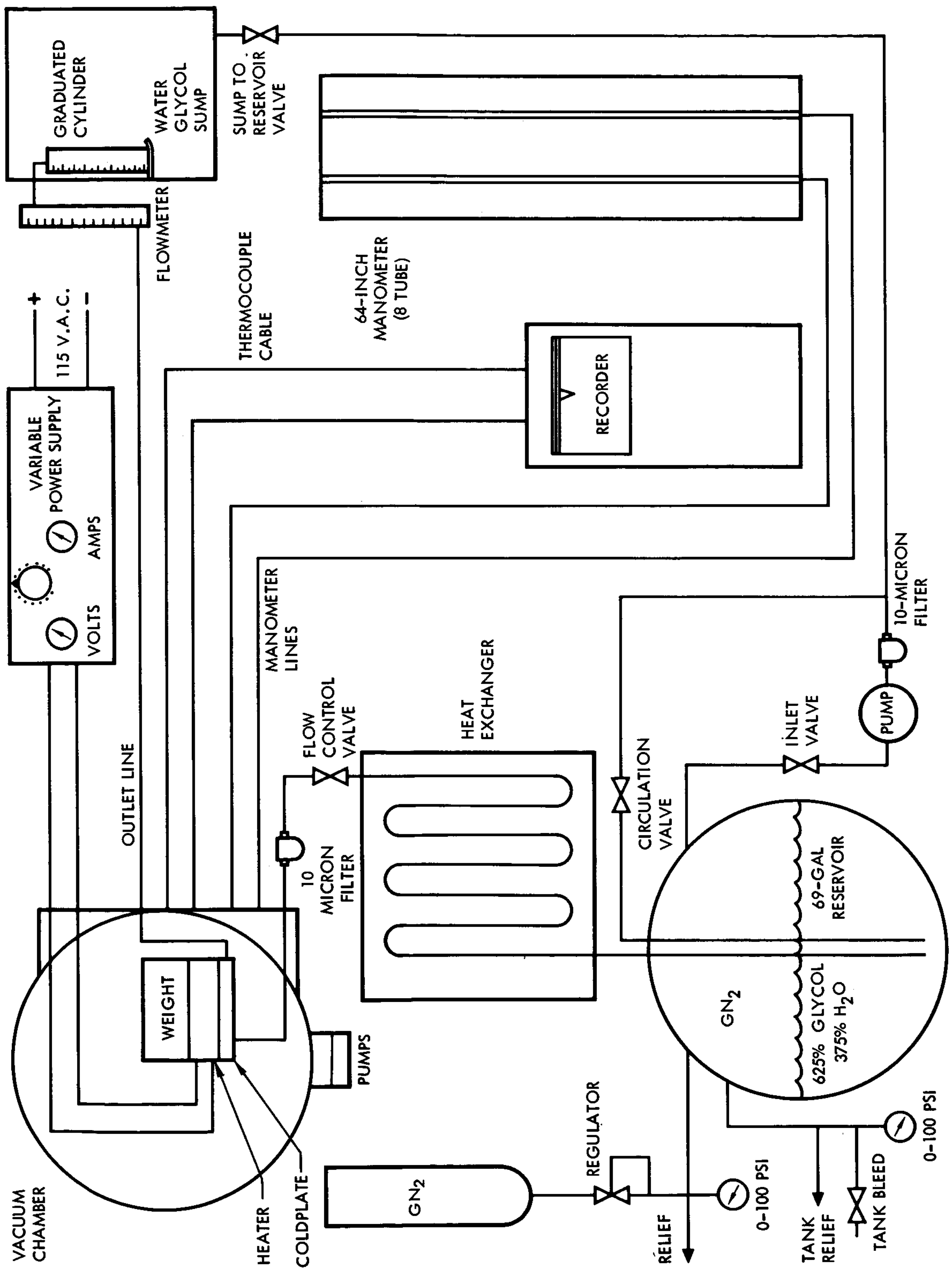

Figure 5-19. Typical Coldplate Thermal Test System

[redacted] [redacted]

[redacted]

5.3.3.2.1.3 Leakage. Each coldplate that successfully passes the hydrostat test will be leak-checked with GN_2 as follows:

1. Attach a regulated GN_2 supply to the coldplate so that pressure may be applied to it internally.

2. Immerse the coldplate in water and pressurize it to 90 psig for 15 minutes.

3. Monitor for any leakage during this time. Any bubbles coming from within the coldplate will be considered a leakage. However, if no bubbles appear within 15 minutes, the test will be considered satisfactory and terminated.

5.3.3.2.2 <u>Thermal Tests</u>

5.3.3.2.2.1 Pressure Drop. The pressure drop across the coldplate will be determined by passing a mixture of inhibited water-glycol (62.50 parts by weight of ethylene glycol, 37.42 parts by weight of distilled water, 1.56 parts by weight of triethanolamine phosphate, 0.156 parts by weight of sodium mercapto benzo thiasole) through the coldplate at ambient room conditions as follows:

1. Connect a water-glycol circulating unit to both the inlet and outlet ports of the coldplate. Connect either manometer or differential pressure gage to these ports.

2. Circulate the water-glycol solution according to the following conditions:

   a. Through coldplate PN V16-614044, V16-614034, V16-614035, V16-614055, V16-614061. Water-glycol circulating conditions are as follows:

Run Number	Flow Rate (lb/hr)	Fluid Inlet Temperature (°F)
1	5	45
2	10	45
3	20	45
4	5	70
5	10	70
6	20	70
7	5	120
8	10	120
9	20	120

[redacted]

[redacted] [redacted]

b. Through coldplate PN V16-614046, V16-614016, V16-614018, V16-614017, V16-614011, V16-4006, V16-614038, V16-614074, V16-614014. Water-glycol circulating conditions are as follows:

Run Number	Flow Rate (lb/hr)	Fluid Inlet Temperature (°F)
1	20	45
2	35	45
3	50	45
4	20	70
5	35	70
6	50	70
7	20	120
8	35	120
9	50	120

c. Through coldplate PN V16-614007, V16-614056, V16-614089, V16-614041, V16-614015, V16-614007. Water-glycol circulating conditions are as follows:

Run Number	Flow Rate (lb/hr)	Fluid Inlet Temperature (°F)
1	40	45
2	55	45
3	70	45
4	40	70
5	55	70
6	70	70
7	40	120
8	55	120
9	70	120

[redacted]

[redacted]

d. Through coldplate PN V16-614047. Water-glycol circulating conditions are as follows:

Run Number	Flow Rate (lb/hr)	Fluid Inlet Temperature (°F)
1	90	45
2	110	45
3	130	45
4	90	70
5	110	70
6	130	70
7	90	120
8	110	120
9	130	120

3. Determine the differential pressure between inlet and outlet ports at each flow rate by observing the manometer or the differential pressure gage.

4. The test will be considered complete when reproducible data ia obtained.

5.3.3.2.2.2 Thermal Gradient. A thermal gradient study of the coldplate will be conducted under ambient room conditions to determine thermal characteristics of the coldplate.

1. Attach thermocouples to the coldplate as shown in Figure 5-20.

2. Connect the coldplate to a water-glycol circulating unit having heating and cooling capabilities. (Install a glycol by-pass around the coldplate so that the water-glycol can circulate without having to pass through the coldplate.)

3. Install a pressure gauge to measure the inlet pressure to the coldplate, a differential pressure gauge to determine the pressure drop across the coldplate, and a flowmeter to measure the fluid flow from the outlet into a graduated container, for periodic checks of the flowmeter.

4. The flow rate will be the nominal value lb/hr indicated on the preceding tables for each group of coldplates and the fluid temperature maintained at 45°F and 120°F respectively.

[redacted] [redacted]

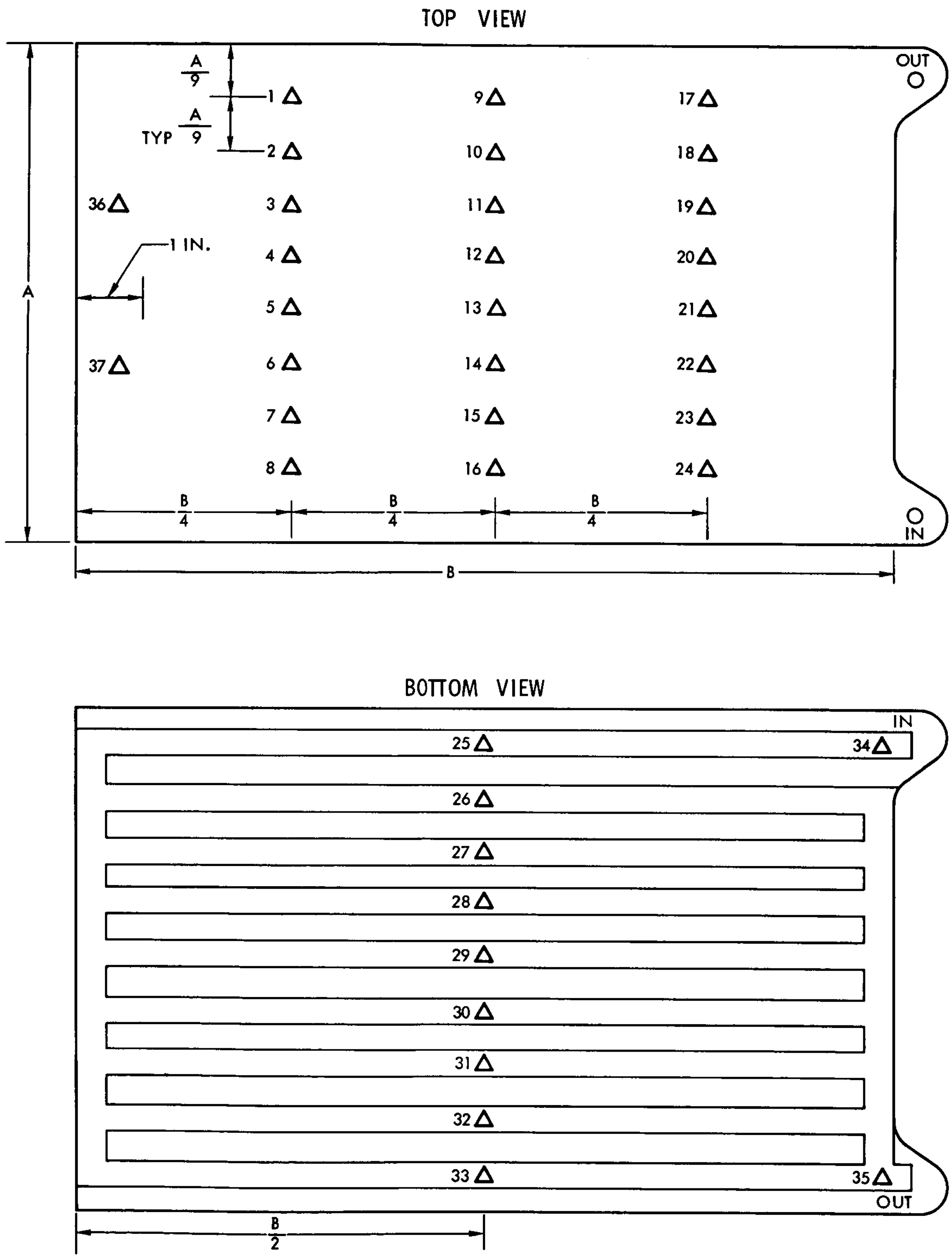

Figure 5-20. Typical Thermocouple Arrangement for Thermal Gradient Testing

[redacted] [redacted]

[redacted] [redacted]

5. After stabilizing the coldplate temperature, record the temperature value of each thermocouple. Continue the test for 20 minutes and note any changes in the temperature reading. Record all pressure readings and terminate the test when accurate data is obtained.

5.3.3.2.2.3 Thermal Conductivity. An interface material of copper foil wrapped silicon tubing soldered to a copper carrier sheet with a composite thickness of 0.156±0.003 inches will be used in the following manner:

a. Wipe the surface of the coldplate and copper carrier sheet with a clean cloth dampened with toluene and then immediately dry the surface with a clean cloth before the solvent evaporates.

b. Apply a thin layer (1 - 2 mils thick) of DC-340 (heat transfer grease) to the surface of the coldplate.

c. Place the thermal interface material on the coldplate, tube side up, and carefully apply pressure to the carrier sheet to insure good contact between surfaces. Care should be taken during this phase to avoid crushing or otherwise damaging the foil wrapped tubing.

The thermal conductivity of the coldplate will then be determined by using a simulated electronic box heat load.

1. Install the simulator on the coldplate compressing the interface material from a thickness of 0.156 inch to 0.130 inch. However, the load on the interface material may not exceed 10 psi. Attach thermocouples to the simulator to determine the heat input to the coldplate.

2. Place the test article in a vacuum chamber and connect a glycol cooling and circulating unit with flowmeter to inlet and outlet ports of the coldplate. (see Figure 5-19)

3. Install two thermocouples respectively on the inlet and outlet ports.

4. Lower the vacuum chamber pressure to 1 x 10^{-4} Torr (maximum pressure), start the water-glycol circulation unit, (make runs according to Tables 5-10 through 5-13) and apply the heat load. (The applied heat load will be one watt per square inch of plate area and evenly distributed over the entire surface.)

[redacted]

5. Allow the system to stabilize before recording any value and determine the heat absorbed by the water-glycol solution at each flow rate. Test may be terminated when accurate data is obtained.

5.3.3.2.3 Structural Tests

5.3.3.2.3.1 Pressure Cycling Test. The coldplate will be pressure-cycled 100 times with GN_2 to verify its capability to withstand varying pressures. The test is conducted as follows:

1. Attach a regulated GN_2 supply to the inlet port and plug the outlet port.

2. Immerse and pressurize the coldplate in water from 0 to 60 psig. Repeat this for 100 cycles, each cycle to be completed within 30 seconds.

3. Monitor for leakage during the test. If after 100 cycles leakage does not appear, the test may be terminated.

5.3.3.2.3.2 Vibration Tests. The vibration test will be performed to verify the structural integrity of the coldplate. It is conducted by installing the coldplate on the vibration test fixture and vibrating it in each of the three major axes as follows:

Random Vibration. Linear increase from 0.01 g^2/cps at 5 cps to 0.06 g^2/cps at 75 cps. Constant at 0.06 g^2/cps from 75 cps to 2000 cps.

Keep the sweep frequency range 15 minutes per axis.

Record all resonant frequencies and the g loads at the resonant frequencies in each of three axes.

Inspect (visually) the coldplate for any damage or indication of failure, both during and after each test.

After completion of the vibration tests, leak-check the coldplate as in paragraph 5.3.3.2.1.3.

5.3.3.2.3.3 Acoustical Test. The acoustical tests verify that a coldplate will withstand the noise pressure levels that could be encountered on an Apollo mission. It is conducted as follows:

1. Install the coldplate in the acoustical chamber so that the sound pressure is uniform over all the surfaces. The natural frequency of the mounting assemblies should be less than 25 cps.

[redacted]

2. Apply the following noise levels at the corresponding octave bands: (The minimum time for sweeping the octave bands is 5 minutes.)

Octave Band	Noise Pressure Level (db)
11.2 - 22.4	113
22.4 - 45	121
45 - 90	127
90 - 180	127
180 - 355	126
355 - 710	127
710 - 1400	131
1400 - 2800	131
2800 - 5600	125
5600 - 11200	118
Over-all	137

3. Visually inspect the coldplate for any indication of failure during and after tests. Upon completion of the test, leak-check as in paragraph 5.3.3.2.1.3.

5.3.3.2.3.4 Acceleration Test. The acceleration tests will verify the coldplate's capability to withstand accelerations it might undergo during an Apollo mission.

1. Mount the coldplate in a test fixture that simulates an actual spacecraft installation.

2. Apply acceleration rate of 20 g's in both directions of each major axis for 5 minutes on each direction.

3. Visually inspect the coldplate for indications of failure during and after the test. After the tests are completed, leak-check the coldplate as in paragraph 5.3.3.2.1.3.

[redacted]

5.3.3.2.3.5 Shock Test. Shock tests will be performed to verify the coldplate's capability to withstand the impact of an earth landing.

1. Install the coldplate in a test fixture, mounting it from the same points from which it will be mounted in the spacecraft.

2. Apply a shock of 78 g's uniformly to the coldplate in a sawtooth wave form for 11±1 milliseconds. Three shocks will be applied in both directions along each of the three major axes. (Peak 78 g's, rise 11±1 ms, decay 1±1 ms.)

3. Visually check the coldplate for any evidence of failure during and after the tests. After the tests are completed, leak-check the coldplate as in paragraph 5.3.3.2.1.3.

5.3.3.2.3.6 Rupture Test. The purpose of this test is to determine the pressure at which the coldplate will rupture when subjected to internal hydrostatic pressure.

1. Place the coldplate in a suitable test fixture so that water pressure may be applied internally.

2. Connect a line to the inlet, apply water pressure, and allow all the air to bleed out.

3. Slowly increase the water pressure until the coldplate ruptures.

4. Record all data, including pressure level when rupture occurs, size and location of rupture, photographs, etc.

5.3.3.3 Network Functional Test

5.3.3.3.1 Equipment

1. Complete set of coldplates

2. Vacuum chamber having minimum dimensions of 5 ft in diameter and 7.5 ft in length and capable of maintaining 1×10^{-4} Torr.

3. Heat-load simulators to be mounted on the coldplates to simulate the electronic boxes.

4. Glycol-water circulating unit capable of supplying the glycol-water solution at flow rates of 0-225 pounds per hour at 40 F to 120 F.

[redacted]

5. Pressure gauges to measure glycol-water pressure at various points in the system.

6. Flow meter to measure the flow rate of the glycol-water in the system.

7. Temperature measuring equipment for measuring glycol-water, heat-load simulator, and ambient-air temperatures.

5.3.3.4 Facilities

The testing program will be conducted in S&ID's engineering development laboratories.

5.3.3.5 Schedules

The schedule for the testing program is shown in Figure 5.21.

The schedule for the ECS radiator manufacturing and test plan is shown in Figure 5-22.

5.3.4 Boilerplate Breadboard Cooling System Tests

5.3.4.1 Test Objectives

The objective of the individual component tests is to verify that each component will perform within its specified operating limits and will meet the requirements of the boilerplate mission, which include, e.g., pressure drop, power consumed, temperature control, and vibration.

The objective of the system test is to verify that the components will function properly when installed in a simulated boilerplate cooling system and subjected to a simulated mission with respect to C/M pressure and heat loads.

5.3.4.2 Test Plan

5.3.4.2.1 Individual Component Tests

1. The motor pump (ME 281-0011) will be placed in a water-glycol system capable of measuring the flow rate of the fluid through the system. The differential pressure across the pump and the power required to operate it will be measured. The pump will be operated in ambient and vacuum conditions. Vibration tests will be performed with the pump operating under load.

[redacted]

[redacted]

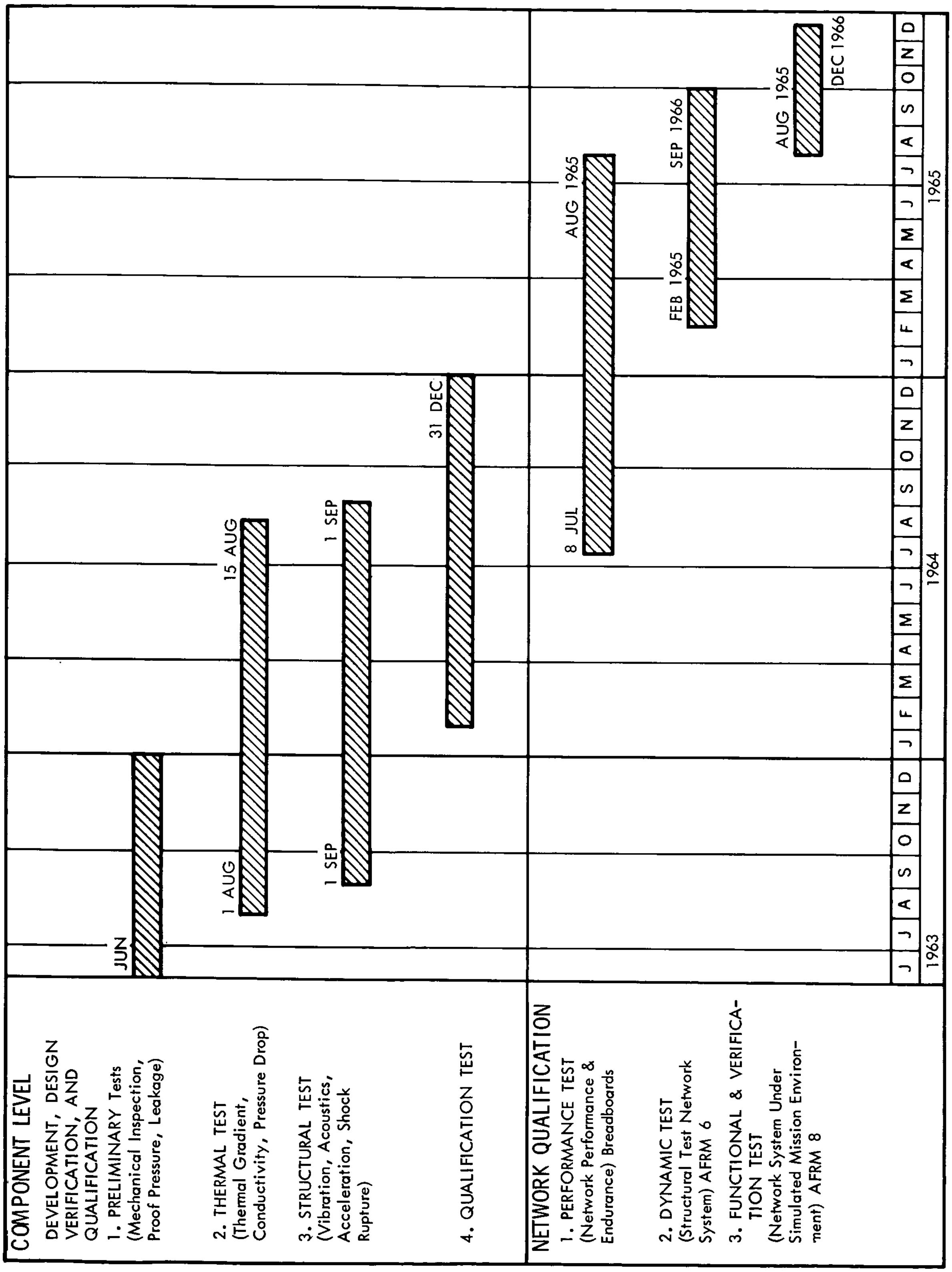

Figure 5-21. Schedule for Coldplate Development Design Verification and Qualification Testing

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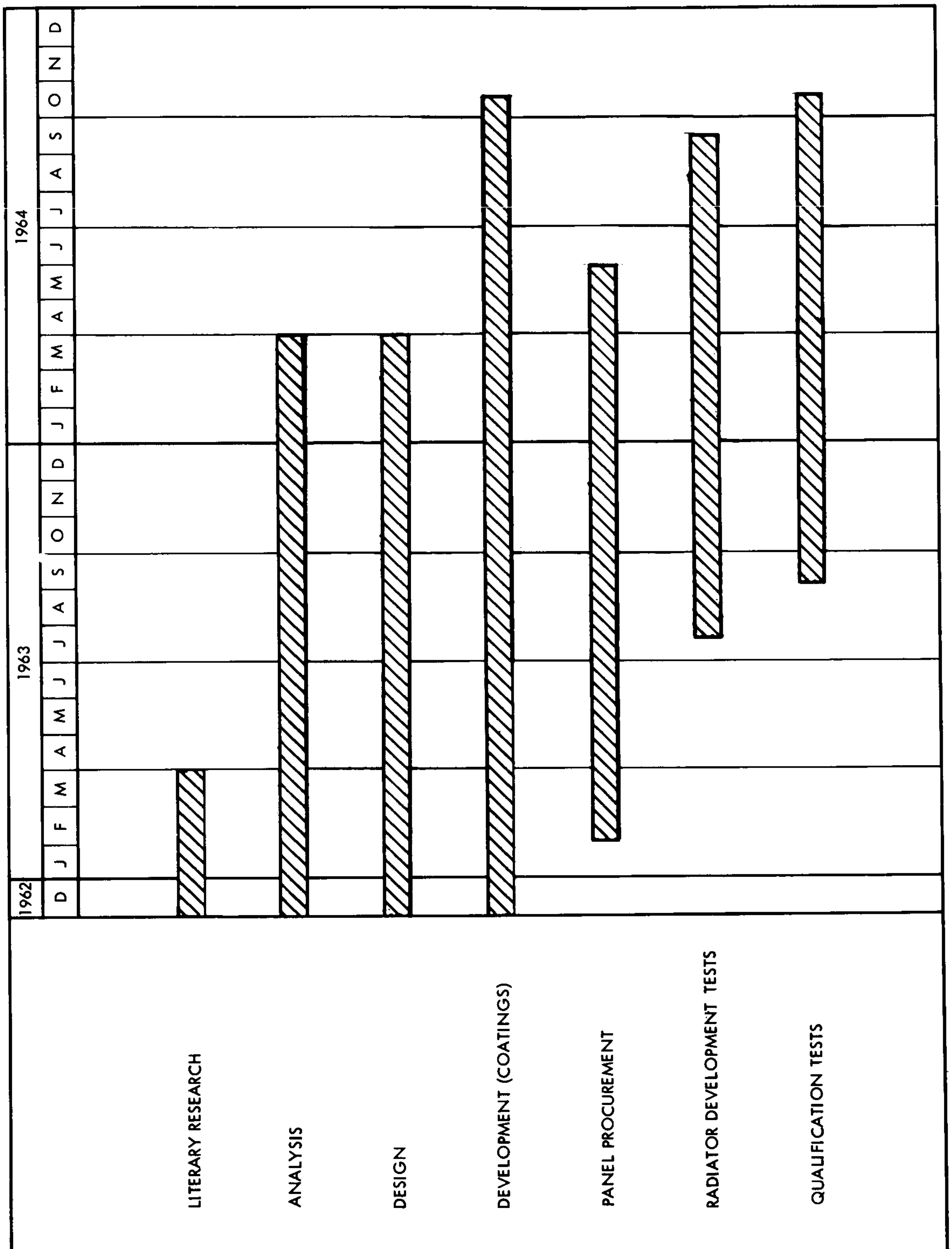

Figure 5-22. Plan for Radiator Manufacturing and Testing

[redacted]

2. The thermal control valve (ME 284-0069) will be installed in a water-glycol system which will have warm and cold reservoirs. The temperature of the cold reservoir shall be +10 F and that of the warm reservoir shall vary between +35 F and +60 F. Warm fluid will be pumped into the valve at a flow rate of 3 gpm and mixed with cold fluid from the cold reservoir. The fluid will then be discharged from the valve at a regulated temperature between +35 F and +42 F. The pressure drop across the valve will be measured at the above flow rate at various inlet temperatures between +35 F and +60 F. Vibration tests will be performed with the valve filled with fluid.

3. The heat exchanger (ME 362-0004) will be connected to a water-glycol circulating system capable of supplying a flow of 3 gpm. The pressure drop across the heat exchanger will be measured at the above flow rate with the by-pass valve in both the open and closed position. Electrical power will be applied to the heat exchanger to operate the fan and solenoid valve. The thermostat will also be checked for proper operation. Vibration tests will be performed with the fan operating and a water-glycol flow through the core of 3 gpm.

5.3.4.2.2 System Test. A simulated boilerplate cooling system will be fabricated with the tubing lengths, bends, and component elevations as similar to the actual system as possible. The system will be placed in a vacuum chamber and instrumentation installed to measure temperatures and pressures at various locations in the system. Also, the power required to operate the pump and heat exchanger fan will be measured. Heat loads will be applied to the coldplates and vacuum chamber atmosphere. A simulated mission will be run with the vacuum chamber pressure lowered at the same rate as the pressure in the command module. Also, the heat loads will be varied to simulate the actual loads. After the test the components will be inspected for any discrepancies caused by the test.

5.3.4.3 Equipment

1. A Boilerplate 13 simulated cooling system made up of production components and tubing of the same size, lengths, and bends as used in the Boilerplate.

2. A cooling and circulating unit capable of cooling 15 gallons of water-glycol to a temperature of +10 F and supplying it to a component at a flow rate of 2-5 gpm.

[redacted] [redacted]

3. A vacuum chamber with a minimum volume of 200 cubic feet and capable of maintaining a pressure of 1 x 10^{-4} Torr.

4. A vibration test fixture capable of vibrating the individual components, which have a maximum weight of 30 pounds, at the levels called out in the test plan. Also, adequate instrumentation will be required to measure the vibration levels imposed.

5. Temperature measuring equipment, including thermocouples and recorders capable of measuring temperatures between +10 F and 225 F with a maximum tolerance of ±1 F.

6. A flowmeter capable of measuring water-glycol flow rates between 2 and 5 gpm at temperatures between +10 F. and +100 F.

7. Various pressure and Δ P gages with a maximum tolerance of ±1 percent.

8. Heat load simulators capable of supplying a 2500-watt heat load to the atmosphere and 585 watts to a set of coldplates. A wattmeter shall be utilized to verify the heat input during test runs.

5.3.4.4 Facilities

The testing program will be conducted in the S&ID Engineering Development Laboratories.

Schedules

The schedule for the testing program of Boilerplate 13 cooling system is shown in Figure 5-23.

5.3.5 Waste Management System Test

5.3.5.1 Objective

The system will be subjected to natural and induced environmental conditions in order to verify design requirements during installation, transportation, handling, storage, and simulated Apollo mission profiles. To evaluate and demonstrate the capability of the ECS waste management system to provide ventilation for the waste, refuse and storage compartments and to provide for the control of gaseous, solid, and liquid wastes within

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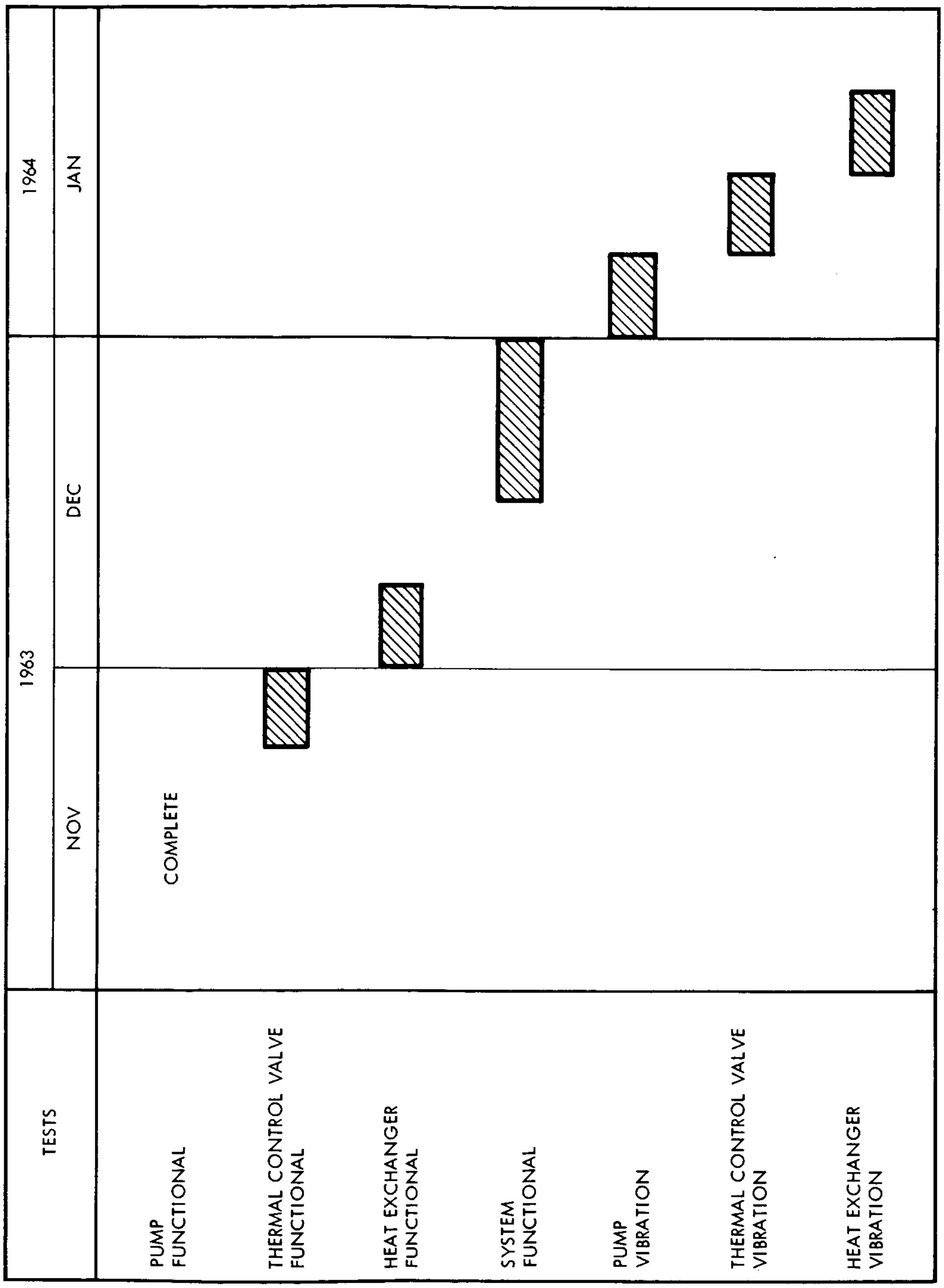

Figure 5-23. Boilerplate 13 Cooling System Testing Schedule

[redacted]

the command module. The waste management system shall also provide disposition of gaseous waste to the ECS for processing, operate for a minimum of 14 days without supply and be able to withstand the dynamic stress to be encountered during the Apollo mission.

5.3.5.2 Test Plan

One complete system shall be utilized for this test program. A schematic drawing of the test specimen is shown in Figure 5-24. It will be built of components that previously have met all acceptance test requirements of S&ID Procurement Specifications. After testing is completed, the tested system shall be returned to the ECS test unit for final disposition. A component that has failed shall be processed as indicated in Paragraph 5.3.5.2.3.5 prior to submittal for disposition.

5.3.5.2.1 Design and Performance Requirements. The waste management system (Figure 5-24) is designed to provide ventilation for the food and waste, refuse, and personal hygiene equipment storage compartments and to provide for the control of gaseous, solid, and liquid wastes within the command module. The WMS shall also provide disposition of gaseous waste to the ECS for processing, operate for a minimum of 14 days without supply and be able to withstand the dynamic stresses to be encountered during the Apollo mission.

5.3.5.2.2 Test Sequence. The system shall be tested in the sequence listed below:

Component Operation

Functional Operation

Vibration

Acceleration

5.3.5.2.3 Test Conditions. Unless otherwise specified herein, all tests shall be performed at an atmospheric pressure between 0 inches and 12.20 inches of mercury, a temperature between 40 F and 75 F, and a relative humidity of not more than 70 percent. Data obtained at other atmospheric conditions shall include necessary correction factors for instrument readings.

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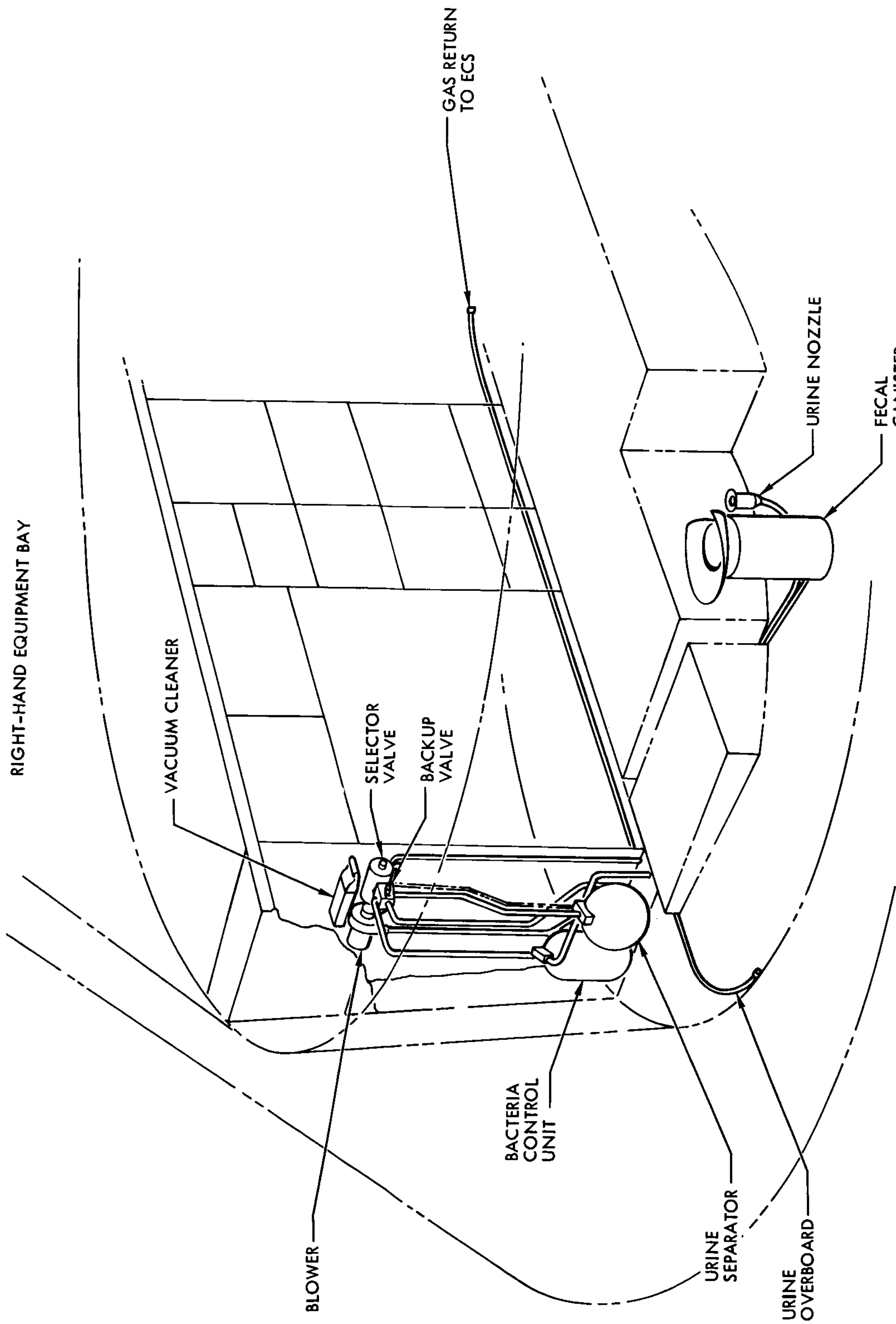

Figure 5-24. Waste Management Installation

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5.3.5.2.3.1 Instrumentation and Installation of Test System. The test system shall be instrumented and installed as shown in Figure 5-25. Test chamber will provide adequate internal and external terminals to permit instrumentation lines for the system.

5.3.5.2.3.2 Pressure. Leak-tight lines shall be connected for both the fluid and air lines. Pressure sensing instruments shall be installed as per Figure 5-25.

5.3.5.2.3.3 Temperature. Copper constantan thermocouples shall be installed as per Figure 5-25.

5.3.5.2.3.4 Flow. Flowmeters shall be installed per Figure 5-25.

5.3.5.2.3.5 Inspection and Failure Criteria. At the end of each test the test system will be visually inspected and a record made of any damage resulting from the test. Damage, deterioration, excessive corrosion, or damage in performance that could in any manner prevent the test system from meeting operational requirements shall provide reason to consider the test item as having failed to withstand the conditions of the tests. After a failure, the test system, with the approval of ECS, may be adjusted or repaired and testing continued.

5.3.5.2.4 Vibration Test. Place test system with support on a test fixture for vibration along each of the lateral axes and along the longitudinal axis. Subject the system to the following conditions along each axis. Scan the frequency range from 5-2000 (cps) in 30 minutes (scanning twice in each of the three major axes, noting the frequency of all resonant points).

Frequency (CPS)	Vibration
5-10	0.030 inch D.A.
10-20	±1.6 G
20-63	0.075 inch D.A.
63-2000	±15 G

Subject resonant frequency will be applied for 5 minutes of vibration in each of the three major axes at the following conditions: 5-20 CPS at 1.6 G, 20-63 CPS at 0.07 inch D.A. Perform leakage test upon completion of vibration test.

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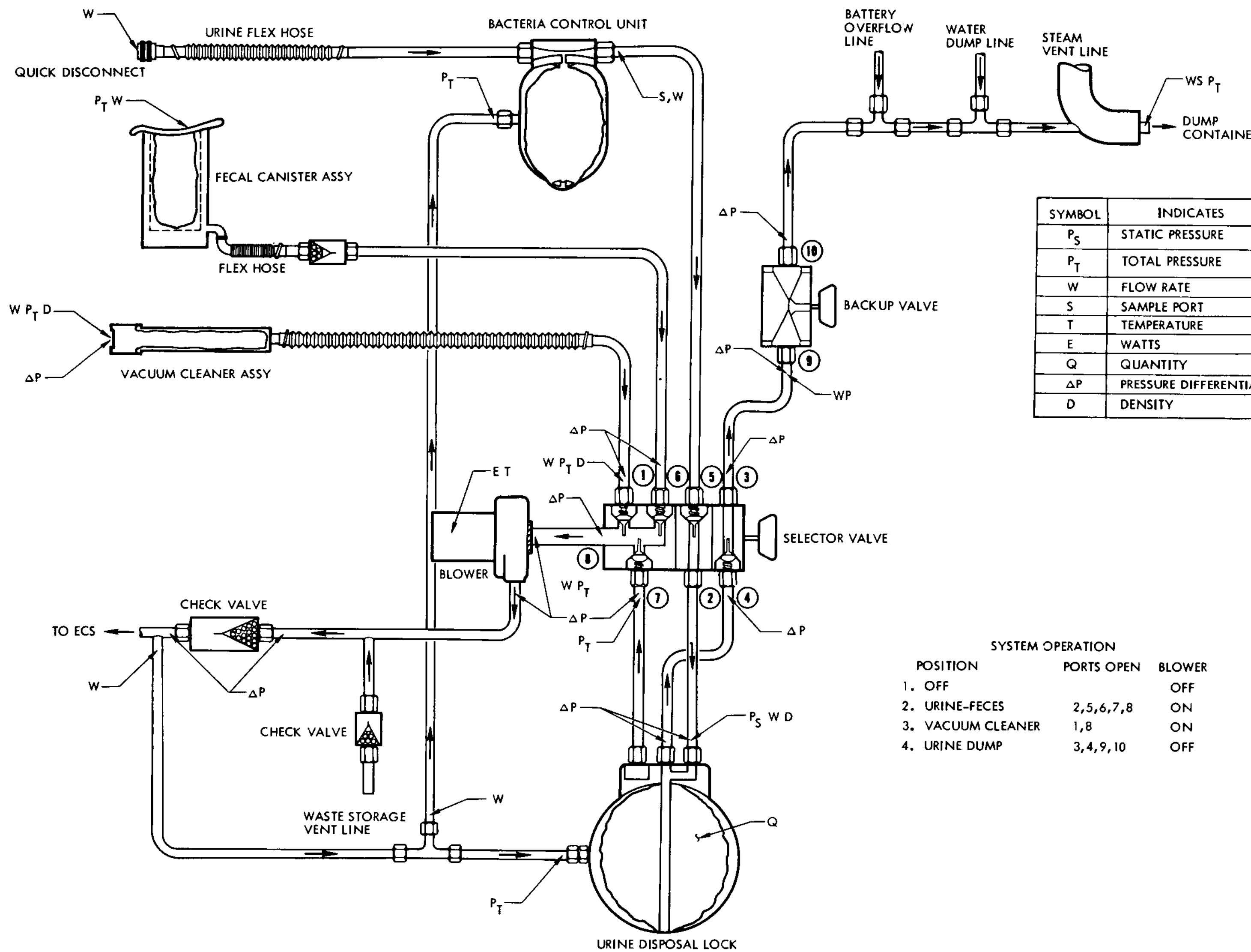

SYMBOL	INDICATES
P_S	STATIC PRESSURE
P_T	TOTAL PRESSURE
W	FLOW RATE
S	SAMPLE PORT
T	TEMPERATURE
E	WATTS
Q	QUANTITY
ΔP	PRESSURE DIFFERENTIAL
D	DENSITY

SYSTEM OPERATION

POSITION	PORTS OPEN	BLOWER
1. OFF		OFF
2. URINE-FECES	2,5,6,7,8	ON
3. VACUUM CLEANER	1,8	ON
4. URINE DUMP	3,4,9,10	OFF

Figure 5-25. Waste Management System

[redacted]

5.3.5.2.5 Acceleration Test. Place test system on test fixture for acceleration application along the major lateral axis in both directions and to permit application of acceleration along the longitudinal axis (flight axis) in the flight direction.

Apply acceleration of 25g for 10±1 minutes along each axis. Perform leakage test upon completion of acceleration test.

5.3.5.3 Equipment Requirements

The items listed and described below represent the major components needed for the component and system testing of the WMS.

1. Space simulation chamber of sufficient capacity to hold WMS.

2. A 100 percent oxygen source

3. Instrumentation and measuring equipment consisting of pressure gauges, differential pressure gauges, flowmeters and an electrical power source for 10-watt blower.

5.3.5.4 Facilities

The waste management system test program will be conducted at S&ID facilities.

5.3.5.5 Test Schedule

The schedule for the testing program is shown in Figure 5-26.

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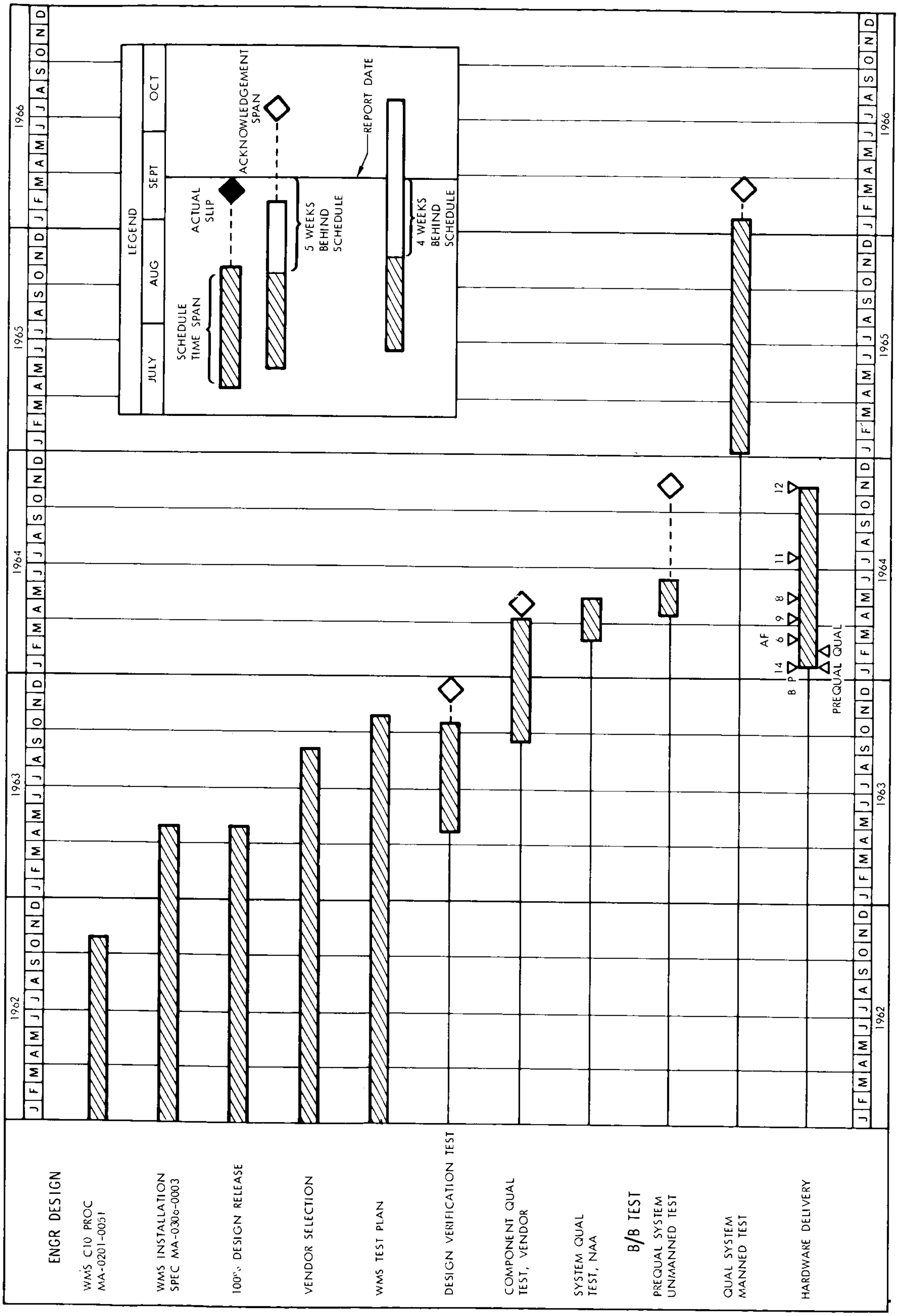

Figure 5-26. ECS Waste Management System Schedule

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6.0 ELECTRICAL POWER SYSTEM*

6.1 SCOPE

Development, design, verification, evaluation, and qualification testing of the electrical power system (EPS) components, subsystems, and systems will be performed jointly by the subcontractor and the prime contractor. The test program includes functional, as well as environmental tests, designed to establish reliable hardware and reliable systems.

6.2 SUBCONTRACTOR TEST PLAN

6.2.1 Fuel Cells (Pratt & Whitney Aircraft)

6.2.1.1 Objective

P & WA is responsible for the design, development, and qualification of fuel cell modules for Apollo missions.

6.2.1.2 Test Plan

P & WA will conduct a multiphase program to encompass design development, component testing, multiple cell testing, single module testing, and qualification testing. During the design development phase, P & WA will develop a design and build multiple cell modules that will produce electrical power for a complete Apollo mission and provide potable water as a by-product suitable for astronaut consumption. Development testing will be performed on components (electrodes, pump separators, by-pass valves, etc.) to the design, off-design, and durability requirements. Self-induced and externally-induced failure modes also will be investigated. Single-module testing will provide data on thermodynamic and module output performance characteristics of the operating system. Qualification testing is performed to establish confidence in the capability of fuel cell power plants to function as a system under selected environments.

*Entire section reissued

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6.2.2 Cryogenic Gas Storage Subsystem

Beech Aircraft's development phase test plan is summarized in the following paragraphs.

6.2.2.1 Objectives

The objectives of the development test program will be to:

1. Evaluate materials, parts, components, and electrical circuits to obtain general intelligence and application suitability data
2. Acquire design or process improvement information
3. Verify that the design approach is compatible with requirements
4. Establish design parameters
5. Establish priorities for testing by determining which components or materials possess the least reliability potential

6.2.2.2 Test Plans

The development tests will include the following tests and test objectives:

6.2.2.2.1 Insulation Structural Tests, Non-Operating. To obtain insulation structural parameters for design.

6.2.2.2.2 Insulation High-Vacuum Acquisition, Non-Operating. To verify the compatibility of insulation material with high-vacuum acquisition by exposing the insulation to a high-vacuum and a measuring outgas rate.

6.2.2.2.3 Insulation Research, Non-Operating. To determine the thermal properties of insulation materials, such as thermal conductivity and physical properties at cryogenic temperatures.

6.2.2.2.4 Flat and 9-Inch Spherical Insulation Segment Vibration Test, Non-Operating. To obtain a damping coefficient and fatigue life data on insulation.

6.2.2.2.5 Tensile Pull Test, Non-Operating. To determine the tensile characteristics of titanium and inconel 718 welded specimens at room and cryogenic temperatures.

6.2.2.2.6 Fan Heater Cleaning Fluid Compatibility Test Non-Operating. To verify the compatibility of fan heater cleaning agents with LOX.

6.2.2.2.7 Liquid Oxygen Fan Heater Impact Test in LO_2, Non-Operating. To verify the impact sustaining capability of liquid oxygen fan heaters by subjecting the fan heaters to impact while at liquid oxygen temperature.

6.2.2.2.8 O_2 Fan Heater Vibration Test, Operating. To determine whether the fan heater assembly can withstand the vibrational environment in local ambient atmosphere and while submerged in H_2O.

6.2.2.2.9 Fan Heater Performance Test, Operating. To determine the performance effects of cryogenic temperatures on one fan heater assembly.

6.2.2.2.10 Concentric Fill and Vent Line Test. To determine the flow rate capability, prove the theory of regenerative cooling, and evaluate the heat transfer characteristics of one each concentric fill and vent line.

6.2.2.2.11 Fill and Vent Coil Test, Operating. Three H_2 and O_2 fill and vent coils will be tested at operating pressures and temperatures to determine the "spring rate," verify proof pressure and burst pressure, and evaluate the capability of the coils to withstand tensile and compression loads while under vibration.

6.2.2.2.12 Joint Test, Non-Operating. To determine the structural integrity of mechanical connections while at cryogenic temperatures.

6.2.2.2.13 Temperature Sensing Probe Test, Operating. To evaluate accuracy, repeatability, response time, and ruggedness of various temperature-sensing devices.

6.2.2.2.14 Rupture Disc Test, Operating. To verify that titanium, aluminum, and inconel rupture discs burst reliably within specified limits.

6.2.2.2.15 Relief Valve Vacuum Vibration Test, Operating. To determine the suitability of the valve to hard vacuum use under vibrational environment.

6.2.2.2.16 Polyphenylether Lab Test, Non-Operating. To determine whether polyphenylether can be used to simulate transient temperature gradient in supercritical oxygen.

6.2.2.2.17 Pressure Vessel Permeation Test. To verify the structural porosity integrity.

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6.2.2.2.18 Pressure Vessel Proof and Burst Test, Operating. To verify proof pressures, determine volumetric expansion and burst pressure, and verify the fabrication techniques on spherical pressure vessels.

6.2.2.2.19 Engineering Model Thermal Tests, Operating. The following tests and test objectives will be conducted on one O_2 storage subsystem and one H_2 storage subsystem to verify that the subsystems will deliver the required flows.

6.2.2.2.19.1 Purge. To purge the storage subsystems prior to filling.

6.2.2.2.19.2 Fill. To verify that the subsystems can be filled in the 40 minutes that are allowed.

6.2.2.2.19.3 Standby Test, Operating. To verify that pressure buildup caused by normal heat leak is not excessive.

6.2.2.2.19.4 Pressure Control and Flow Rate Test, Operating. To verify that the electric heaters are adequate for pressurization and maintaining flows.

6.2.2.2.19.5 Vacuum Chamber Test. To verify that the storage tanks are capable of delivering the required flows in a vacuum environment.

6.2.2.2.19.6 Quantity Balance Control Test, Operating. To verify that the quantity balance control can maintain equal quantities of stored medium in the two tanks of the storage subsystem.

6.2.2.2.19.7 Vacuum Loss and Relief Valve Flow Test, Operating. To determine the effects from the loss of insulating vacuum and verify that the relief valves are capable of handling the resulting flows.

6.2.2.2.20 Engineering Model Drop and Performance Test. To verify that shipping containers are adequately designed and fabricated.

6.2.2.2.21 Engineering Model Vibration Test, Operating. To verify that the storage tanks operate as required under vibration.

6.2.2.2.22 Engineering Model Rupture Disc and Outer Shell Rigidity Test, Non-Operating. To verify that the rupture discs perform as required, and evaluate the strain on the outer shell.

6.2.2.3 Subcontractor Test Schedule

Figure 6-1 shows the subcontractor test schedule.

6.2.3 Power Distribution and Conditioning System

6.2.3.1 Static Inverter (Westinghouse)

6.2.3.1.1 Objective. To verify the design of and to qualify the inverter per subcontractor test plans, as approved by S&ID. More specific objectives are to develop and test the solid-state inverter (115/200-volt, 400-cps, 3-phase) to establish minimum harmonics and RFI generation, stable voltage and frequency, maximum efficiency, and minimum size and weight. These characteristics will be optimized under temperature variations and load cycling. Operational temperatures are to be held below 120 C.

6.2.3.1.2 Test Plan. Westinghouse will perform development tests of circuits and evaluation of components as required to minimize size, weight, harmonic distortion, acoustic noise and RFI generation, and to assure the required reliability. In addition, Westinghouse will determine the effects of the coolant temperature variations and other environments such as high- and low-temperature, humidity, altitude, shock, vibration, acceleration, radio frequency and electromagnetic interference, life test, leak tests and off-limit load tests.

6.2.3.1.3 Equipment. The following test equipment is required:

1. Humidity chamber
2. Temperature chamber
3. Altitude chamber
4. Vibration machine
5. Shock tower
6. Centrifuge

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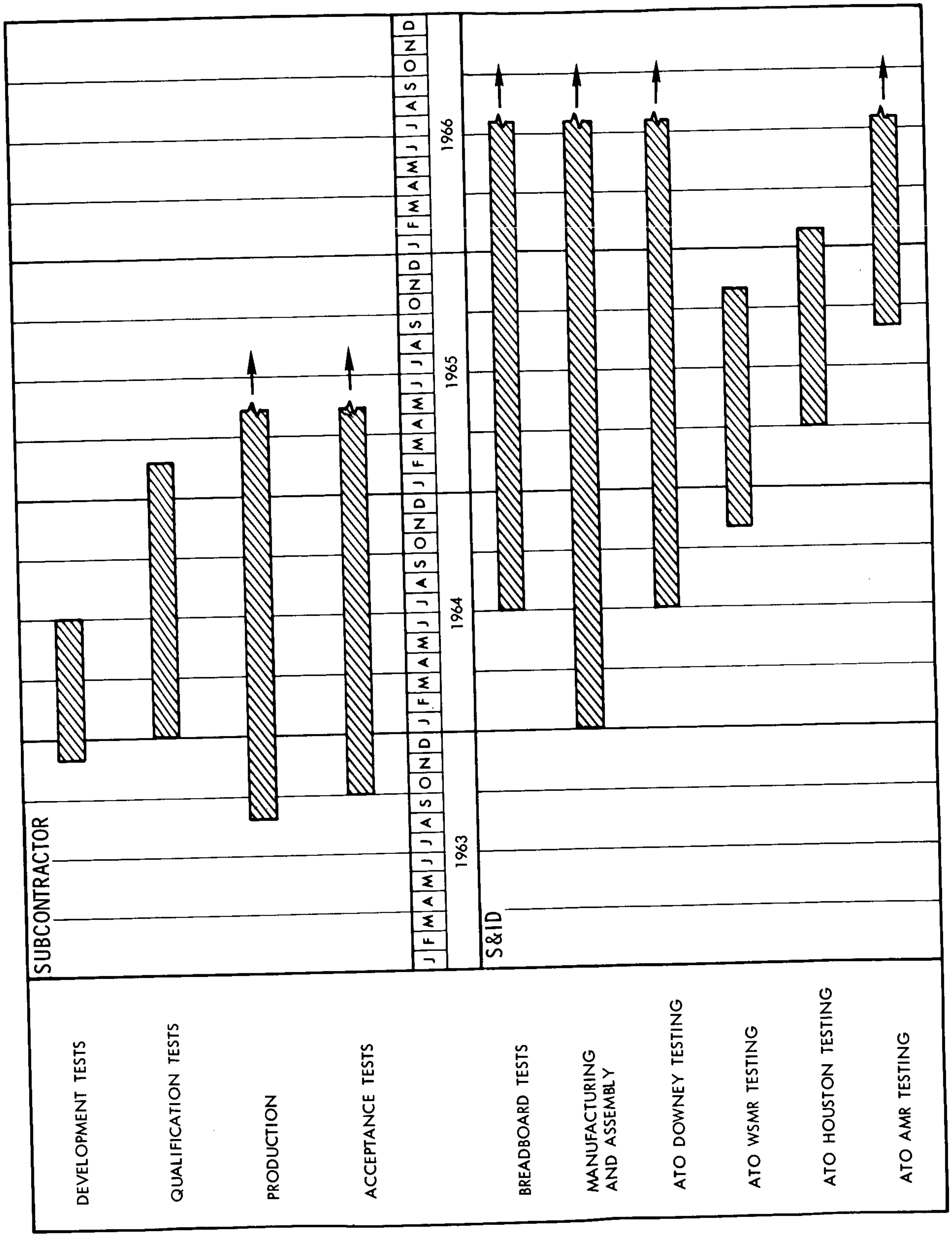

Figure 6-1. Cryogenic Gas Storage System Testing and Production Schedule

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6.2.3.2 Entry and Postlanding Batteries (Eagle-Picher)

6.2.3.2.1 Objective. To verify the design of the zinc-silver oxide batteries and qualify them per the Apollo program requirements. The design effort will be centered around packaging, as the cells are standard units. Pressure tests of the case to determine rupture pressure, seal qualities, and positive pressure release or venting are most critical. Long term tests will determine the effects of temperature variations and activated cell (discharged) storage on cell separators and battery capacity.

6.2.3.2.2 Test Plan. The subcontractor will be responsible for conducting sealing tests and simulated battery over-gassing tests. In addition, Eagle-Picher will operate the batteries in the various environments applicable to the battery including: low- and high-temperature, temperature shock, altitude, shock, vibration, acceleration, humidity, life test, and leak tests. Storage tests in both the charged and discharged (activated) conditions also will be conducted to determine the effects on capacity.

6.2.3.2.3 Equipment. The following equipment will be required:

1. Low-high temperature chamber
2. Altitude chamber
3. Vibration machine
4. Shock tower
5. Centrifuge
6. Miscellaneous equipment
7. Humidity chamber

6.2.3.3 Pyrotechnic Batteries (Electric Storage Company)

6.2.3.3.1 Objective. The subcontractor will verify the design of the zinc-silver oxide batteries and qualify them per S&ID procurement specification MC 461-0007A. The design effort will be centered around packaging. Pressure tests of the case to determine rupture pressure, seal qualities, and positive pressure release or venting are most critical. Long term tests will determine the effects of temperature variations and activated cell (discharged) storage on cell separators and battery capacity.

6.2.3.3.2 Test Plan. The subcontractor will be responsible for conducting sealing tests and simulated battery over-gassing tests. In addition, the subcontractor will operate the batteries in the various environments applicable to the battery including: low- and high-temperature, temperature shock, temperature altitude, shock, vibration, acceleration, humidity, life test, and leak tests. Storage tests in both the charged and discharged (activated) conditions also will be conducted to determine effects on capacity.

6.2.3.3.3 Equipment. The following equipment will be required:

1. Low-high temperature chamber
2. Altitude chamber
3. Vibration machine
4. Shock tower
5. Centrifuge
6. Humidity chamber
7. Miscellaneous equipment

6.2.3.4 Battery Charger (International Telephone and Telegraph Corporation)

6.2.3.4.1 Objective. The objective of the development test plan is to verify and improve the design of and qualify the charger per S&ID procurement specification MC 461-0002C. The tests will be directed toward increasing efficiency and regulation; reducing size, weight, and RFI generation; as well as providing assurance that the charger cannot overcharge the battery.

6.2.3.4.2 Test Plan. The subcontractor will perform developmental tests of components and circuits to reduce weight, acoustical noise generation, RFI generation, RFI susceptibility, sources of RFI and the number of components, as well as to increase efficiency and regulation. Battery charging tests will be performed. Tests also will be performed to assure current limiting ability of circuitry and the stability of charging voltage cut-off during expected environments of high- and low-temperature, humidity, shock, vibration, life cycle, off-limit tests, acceleration, and acoustic noise.

6.2.3.4.3 Equipment. The following equipment will be required:

1. Temperature chamber
2. Altitude chamber
3. Shock tower
4. Vibration machine
5. Centrifuge
6. Humidity chamber
7. Cycling equipment
8. Miscellaneous equipment

6.2.4 Electrical Wiring and Equipment Subsystems

6.2.4.1 Umbilicals (ITT-Cannon Electric Company, Inc.)

6.2.4.1.1 Objectives. Cannon Electric will be responsible for development and qualification of all umbilicals and pressure-barrier feed-through connectors used in the Apollo vehicle. The objectives of the subcontractor test program are:

1. To determine the effect of high-differential temperatures on the sealed insert
2. Guarantee pressure seals during all environments expected in the Apollo mission
3. Assure compliance with specified electrical characteristics and mechanical requirements

6.2.4.1.2 Test Plan. Cannon Electric will conduct the following program to verify the design and establish reliability of the umbilicals and pressure-barrier feed-through:

1. Verify electrical and physical compatibility with spacecraft requirements

2. Verify pressure-barrier feed-through throughout the low-temperature, high-temperature, pressure range, acoustic vibration, shock, and acceleration environments

6.2.4.1.3 Equipment. The following test equipment will be used on this phase of the program:

Vibration machine

Temperature-altitude chamber (400,000 feet)

Acoustic-vibration chamber

Shock tower

Centrifuge

Megger and hypot

Humidity chamber

6.3 S&ID TESTS OF NAA OR SUBCONTRACTOR COMPONENTS

6.3.1 Fuel Cell Test Plan

6.3.1.1 Scope

The early experimental testing of single modules at the Pratt and Whitney facilities supplements the fuel cell system testing now underway. Tests will be conducted by the Engineering Development Laboratories at S&ID, Downey, California, to determine the effects of operating variables on fuel cell performance, establish the limits of performance of the powerplants, and initiate further evaluation of fuel cell performance to determine such parameters as thermodynamic characteristics, load sharing, reactant regulation, etc. The Apollo electrical power systems group will coordinate all phases of the test.

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6.3.1.2 Objectives

Prime objectives to be accomplished during the performance of evaluation tests are (Tables 6-1 and 6-2) to:

1. Determine the minimum and maximum power output

2. Obtain specific fuel consumption, pressure, temperature, water production, water pH data, and determine water purity

3. Determine start-up characteristics

4. Determine transient response time to load variations

5. Assess performance of regulators, heat exchangers, water separators, and other mechanical systems

6. Determine radiator performance and heat-dissipation characteristics

7. Determine start, hold, and stop capabilities

8. Evaluate parallel operation

9. Verify start, stop, and operating procedures

6.3.1.3 Test Plan

S&ID tests will be divided into categories reflecting the specialized facility requirements, rather than listing categories being performed.

6.3.1.3.1 Engineering Development Laboratory. Twelve prototype and conditionally qualified fuel cell powerplants, supercritical reactants, and all off-the-shelf components (resistors, regulators, heat exchangers, etc.) will be utilized to evaluate the fuel cell powerplant functional characteristics, and to compile data to finalize design of support components. During the final stages of the test program, the EPS and ECS subsystems will be integrated to determine and correct any degrading interaction that may result from the combined systems. Some specific objectives of the fuel cell tests are to:

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Table 6-1. Fuel Cell Tests

Test Service Module Evaluation	Test Description	Items to be Monitored
Leakage	Pressurize module utilizing He for H_2 and N_2 for O_2	Pressure
Insulation resistance	Measure the electrical resistance of thermal insulating materials	Megohms
Start-up	During preheat cycling, evaluate power required, the hot N_2 purge requirement, terminal voltage, and module temperature as reactants are applied	Volts, a-c current, watts, time, and module temperature
Voltage regulation	Apply resistive loads in steps from zero to maximum and measure all values as steady-state condition	Volts, d-c current, and all module instrumentation
H_2O Production	Evaluate water production, pH, purity, and pump power. Glycol and water separator pumps are on the same line, therefore, both are check concurrently	The pH meter, sampling equipment, and flow meter
Reactant utilization	Effect of initial reactant temperature and pressure on power output	Voltage, current, and all powerplant instrumentation points
Heat rejection	Determine total heat rejection of the complete fuel cell powerplant system	Glycol flow, glycol pressure, and glycol temperature
Parallel module operation load cycling	Vary loads and observe regulators for hunting and overshoot	Each module, volt, current, reactant pressure, and module instrument points

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Table 6-1. Fuel Cell Tests (Cont)

Test Service Module Evaluation	Test Description	Items to be Monitored
Transient response	Change resistive load of various magnitudes, constantly monitoring voltage and current	Volt, time, current, and all module instrument points
Load sharing	Load sharing for various loading conditions and effect on load sharing by incomplete purging, module temperature, and pressure variations	Voltage, current, and all module instrumentation points
Heat rejection	Determine total heat rejection of the complete fuel cell power system	Glycol flow, glycol pressure, glycol temperature, voltage, current, and H_2
EDS and EPS	Determine load sharing between fuel cell and batteries	Voltage, battery current, and fuel current
Failure mode	Determine the time that modules will operate under various loads when auxiliary pumps are not operational	Volts d-c; volts a-c; and time
ECS and EPS	Maximum oxygen flow rate	Volt, current, and oxygen
EPS and ECS	Man-rating of ECS chamber	All powerplant instrumentation

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Table 6-2. Heat Rejection Tests

Type of Test	Test Plan	Range of Values	Accuracy
Radiator performance	Determine inlet and outlet temperature and heat dissipation in thermal vacuum chamber	10^{-4} mm Hg	
Radiator inlet temperature	Measure glycol inlet temperature	0 to 250 F	±5 degrees
Radiator outlet temperature	Measure glycol outlet temperature	-35 to +240 F	±5 degrees
Radiator temperature	Determine equilibrium temperature at minimum and maximum heat load under simulated space environment		
Radiator pump power	Determine power consumption at minimum and maximum heat load conditions	0 to 30 watts	
Radiator transients	Verify that fuel radiator response is rapid enough to ensure no detrimental effect on fuel cell system power output in all external environments		

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1. Verify the operational characteristics of a single module powerplant

2. Demonstrate the characteristics of parallel powerplant operation

3. Demonstrate the compatibility of fuel cells and battery parallel operation

4. Demonstrate the compatibility of fuel cells and inverters

5. Demonstrate the compatibility of fuel cells with Dewar storage containers

6.3.1.3.1.1 Operational Performance (Single Powerplant). In this portion of the test only, all electrically excited components within the fuel cell are to be operated from external power sources.

6.3.1.3.1.1.1 Contamination Analysis.

Particulate (gas and water) The particulate contamination level on a minimum sample of each gas used will be determined. Particle count and microscopic technique will be compatible with SAE ARP-598.

Purity (water) An analysis will be performed to determine the presence of organic and inorganic contaminants. Subsequently, any large or unusual particle counts are justification for additional chemical analyses.

Purity (gas) Each of the pressurized gases will be subjected to a grade A-type purity test. Any alteration of the source supply will require additional chemical analysis.

6.3.1.3.1.2 Powerplant Parallel Operation. Each powerplant will be subjected to individual testing to determine normal operational characteristics prior to being paralleled. After being electrically connected together, the following test objectives are to be investigated in addition to verification of the individual performance characteristics of the parameters considered in the single powerplant tests:

1. Load sharing capabilities

2. Voltage regulation characteristics

3. Transient response times

4. Voltage balance versus venting

[redacted]

[redacted]

5. Voltage recovery time

6. Load handling capability

7. Temperature equalization

6.3.1.3.1.3 Integrated Test with Electrical Distribution System. In portions of this test it will be necessary to have batteries capable of operating at 30-volts dc. This portion of the test will be coordinated with the electrical design group which has battery responsibility.

6.3.1.3.1.4 Powerplant Operations with Hydrogen and Oxygen, Apollo Storage Tank. This phase of the test program will be coordinated with the cryogenic storage systems group which has Apollo Dewar storage container responsibility.

6.3.1.3.2 Spacecraft. House Spacecraft 1 (BP 14), a skeletal structure spacecraft, will be utilized to determine and resolve mechanical and electrical interface problems. Systems interaction, response time of regulators utilizing spacecraft plumbing, electromagnetic interference, and evaluation of design changes will be a few of the problems to be resolved.

The propulsion spacecraft (AFRM 001) is a spacecraft that will be utilized primarily for verification of propulsion system installations and subsequent operations under static-firing conditions. Fuel cells will be tested on this vehicle to determine the ability of fuel cells to operate under these simulated firing conditions, to provide electrical power to some of the on-board components, and to determine whether the GSE can monitor significant fuel cell parameters such as temperature, pressure, water pH, etc. A secondary purpose is to evaluate the methods of servicing (loading and unloading) vehicles with cryogenic reactants. The successful completion of this series of tests will permit continued testing of fuel cell modules at other facilities where the basic criteria will be operation in a vacuum chamber under simulated mission conditions.

House spacecraft (AFRM 006) will contain prototype systems; thus, the over-all fuel cell operating characteristics can be determined and evaluated. During the final phase of the program, the operating system within the spacecraft will be subjected to the dynamic environments of vibration and acoustic noise.

The fuel cell system installed in the environmental spacecraft (ARFM 008) will utilize the finalized system components - radiators, isolation valves, etc. - and will be subjected to a simulated mission while furnishing power to other spacecraft systems. The basic advantage to testing under

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these conditions is to evaluate problems related to heat rejection under simulated mission conditions. A 10^{-4} vacuum and simulated solar radiation source will be utilized.

6.3.1.4 Equipment

The following is a list of the major pieces of equipment required to conduct the basic powerplant test sequences. These test articles will be assembled in various configurations and will be supplemented by specialized GSE equipment for the spacecraft test participation phases.

- Voltemeters
- Ammeters
- Wattmeters
- Recording oscillograph
- Pressure transducers
- Gas analyzer
- Flow meter
- Vacuum gauge
- Ground support power supply
- Heat sink
- Nitrogen heater
- Vacuum chamber
- Filters
- Temperature transducers

6.3.1.5 Facilities

Additional test facilities required for performance verification and compatibility tests at S&ID are currently under construction. A semi-remote building capable of handling the hazardous materials involved with the fuel cells has been provided together with facilities for reactant storage, test stands, and special instrumentation.

6.3.1.6 Test Schedules

The program schedule for the Apollo fuel cell system is shown in Figures 6-2 and 6-3.

6.3.2 <u>Cryogenic Gas Storage Subsystem</u>

S&ID's breadboard, manufacturing and assembly (SMD) and Apollo test operations (ATO) systems and integrated systems tests are outlined in the following paragraphs.

6.3.2.1 Objectives

The objective of the breadboard tests will be to verify that the ECS, CGSS and EPS are compatible and do, in fact, function as required.

The objective of the manufacturing and assembly (SMD) test will be to verify that the CGSS system is assembled in the correct configuration, that these has been no physical damage done to any part of the system, that

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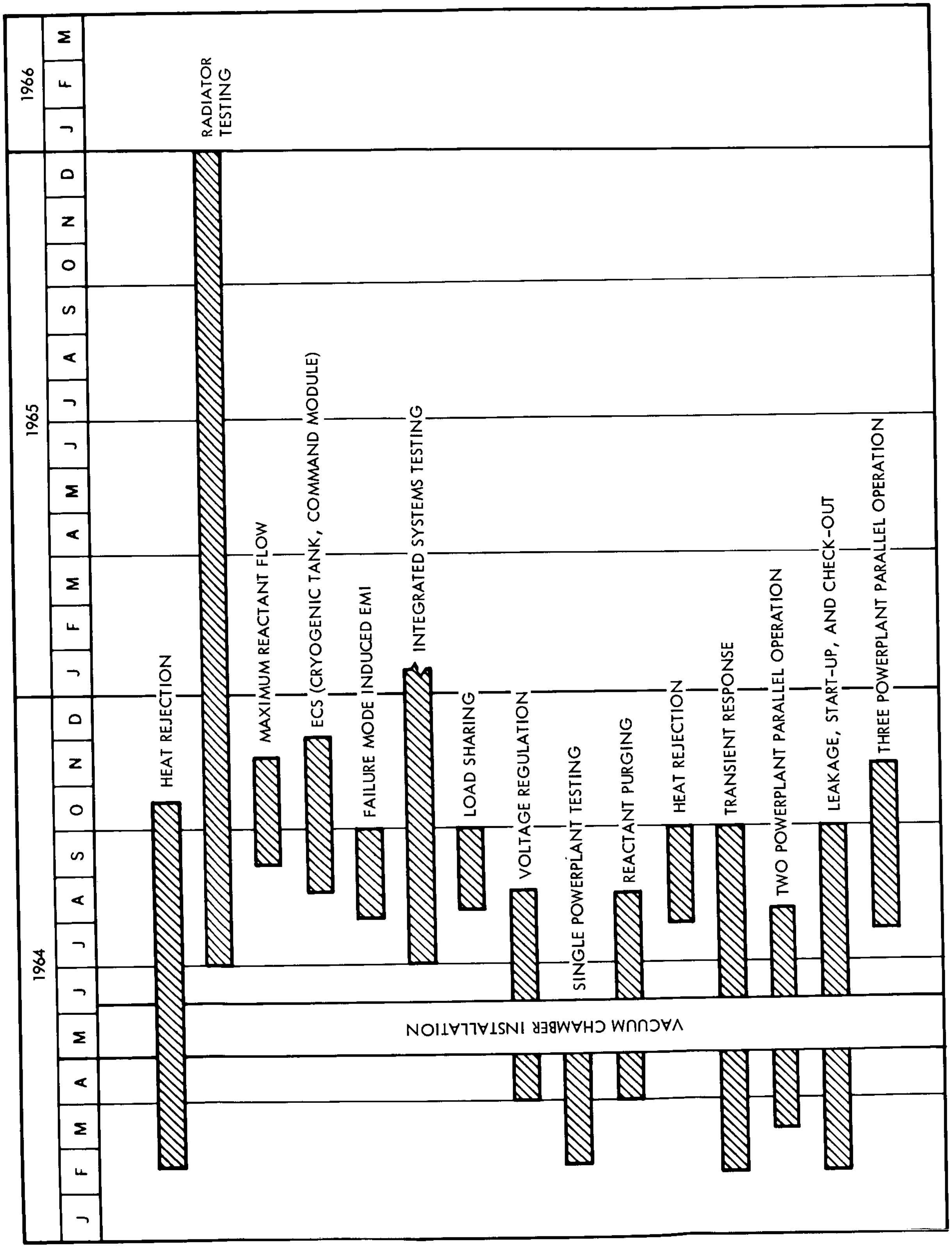

Figure 6-2. Fuel Cell Development Phasing Schedule

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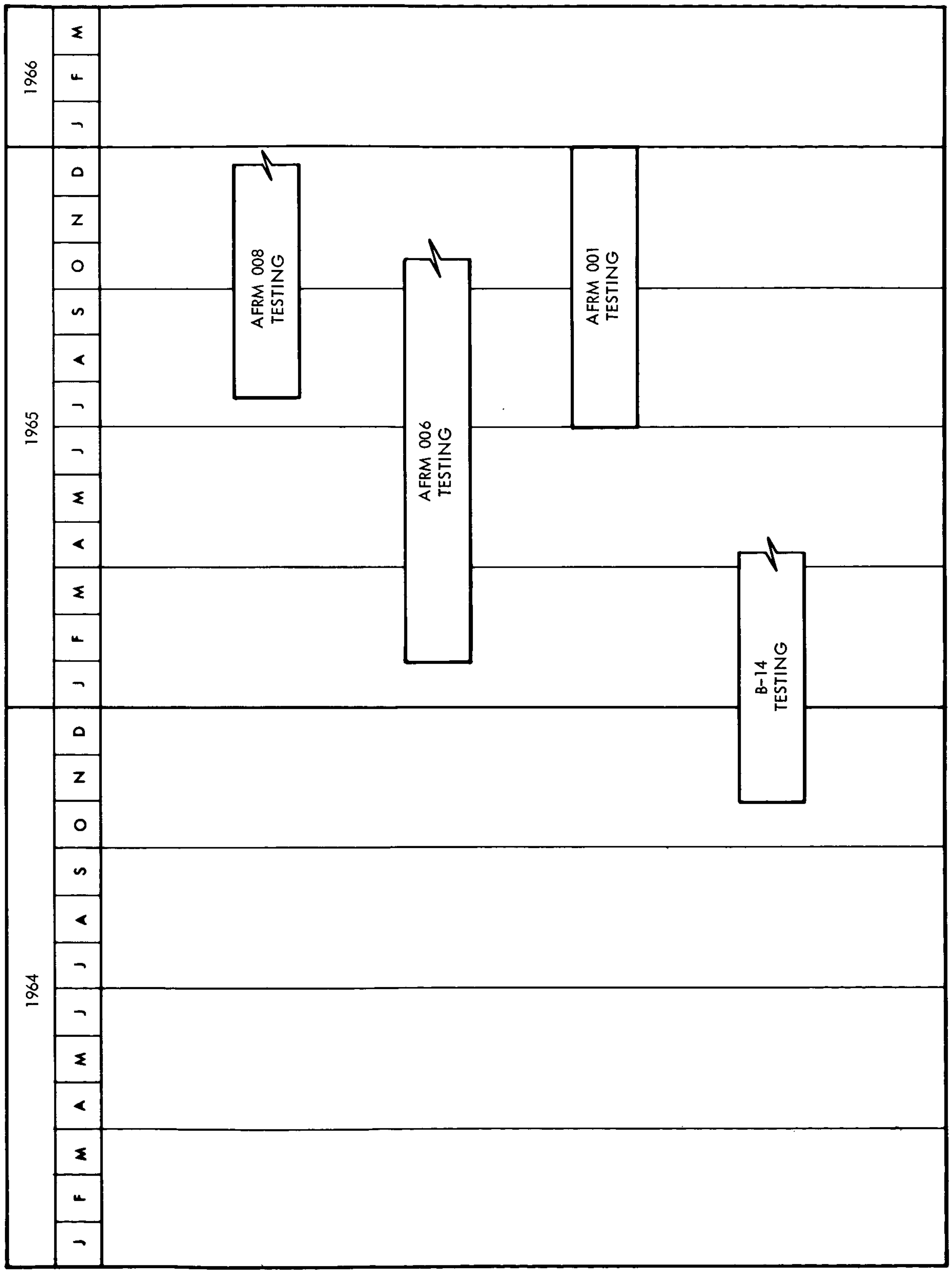

Figure 6-3. Spacecraft Fuel Cell Test Schedule

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there are no leaks in the assembled system, and that the required cleanliness levels have been maintained.

The objective of the Apollo test operations will be to verify the functional integrity of the system on the system and integrated system levels.

6.3.2.2 Test Plans

6.3.2.2.1 Breadboard Tests. The CGSS breadboard tests which will be conducted in Downey will include the following tests and test objectives:

6.3.2.2.1.1 Fill Procedure Verification. To verify that the service and checkout procedure does provide an optimum method for fill and checkout of the CGSS.

6.3.2.2.1.2 Simulated Mission Profile Operation. To verify that the CGSS is capable of supplying the required fluids to the ECS and EPS.

6.3.2.2.1.3 Pressure Response Test. To obtain information on the pressure control response of the CGSS due to changes in flow.

6.3.2.2.1.4 Emergency Flow Test. To verify that the CGSS is capable of supplying emergency flows to the ECS and EPS.

6.3.2.2.1.5 Over Pressure and Relief Valve Test. To verify that the relief valves crack and flow within the specification limitations.

6.3.2.2.1.6 Hold Time Capability. To verify that the CGSS is capable of holding for the required length of time without over pressurization due to heat leak.

6.3.2.2.1.7 Surge Tank Emergency Flow Test. To verify that the CGSS is capable of supplying the required flow to the ECS for surge tank emergency flow.

6.3.2.2.1.8 Surge Tank Fill Test. To verify that the CGSS is capable of filling the surge tank.

6.3.2.2.1.9 ECS Flow Control Test. To verify that the CGSS is capable of controlling the flow from the CGSS to the ECS.

6.3.2.2.1.10 ECS Flow Line Heat Transfer Test. To verify that the heat leak characteristics of the ECS flow lines are within the anticipated design ranges.

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6.3.2.2.1.11 EPS Flow Line Heat Transfer Test. To verify that the heat leak characteristics of the EPS flow lines are within the anticipated design ranges.

6.3.2.2.1.12 Heater and Pressure Switch Operation Test. To verify that the pressure switches and heaters are capable of maintaining the pressure in the tanks within the specified design limits throughout a mission.

6.3.2.2.1.13 Flight Instrumentation Test. To verify the acceptability of the flight instrumentation for the various measurements.

6.3.2.2.1.14 System Quantity Balance Verification. To verify that the pressure switch circuit is capable of maintaining a quantity balance between the two tanks of each subsystem within the limits specified.

6.3.2.2.2 Manufacturing and Assembly Tests. The manufacturing and assembly tests performed at Downey will include the following tests and test objectives:

6.3.2.2.2.1 Visual Inspection of Components and System. To verify that there are no visual physical defects in the components or assembly of the system due to transport.

6.3.2.2.2.2 Electrical Checkout Test. To verify that the electrically interfaced components of the CGSS are operable and function as required.

6.3.2.2.2.3 Leak Check Test. To verify that the assembled systems leakage rate is within the specification limitations.

6.3.2.2.2.4 System Functional Checkout Tests. To verify that the assembled system is operational. Tests will include checking relief valves crack, full flow, and reseat pressures, and pressure switch actuation pressure checks.

6.3.2.2.3 Apollo Test Operations (ATO). The ATO will include the following tests and test objectives on the specified boilerplates and airframes:

6.3.2.2.3.1 Boilerplate 14. The object of B-14 cryogenic system tests is to determine preliminary electrical power requirements and to verify that the electromagnetic interference (EMI) requirement is met and to assure that EMI effect between subsystems is within the specified limit for the overall vehicle. The electrical power profile information obtained from B-14 will be preliminary only, since no cryogenic testing is possible due to safety regulations and hardware limitation.

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6.3.2.2.3.1.1 EMI Test Objective. To verify that the EMI requirements are met, and if need be, to give direction for redesign to avoid possible EMI problems.

6.3.2.2.3.1.2 Electrical Power Requirements Profile Test Objective. To gain preliminary information as to the actual electrical power requirements.

6.3.2.2.3.2 AFRM 001. AFRM-001 tests are performed on the subsystem level as well as an integrated system with fuel cell and the electrical distribution, but not with the ECS since AFRM 001 does not have a C/M. ECS flow simulation will be provided. The AFRM 001 testing at WSMR is divided into two phases. The first phase is a series of static firing tests performed on the service propulsion systems (SPS). The second phase is a series of tests performed to determine effects on operating systems as a result of static firing of the engines.

ATO tests at Downey on AFRM 001 will include the following tests and test objectives:

6.3.2.2.3.2.1 Leakage Checkout Tests. To verify that the system is not leaking excessively after acceptance by ATO from Manufacturing.

6.3.2.2.3.2.2 Electrical Checkout Tests. To verify the electrical operability and continuity of the electrically-interfaced components.

ATO tests at WSMR will include the following tests and test objectives:

6.3.2.2.3.2.3 Service and Checkout Procedure Checkout. To verify operability of the service and checkout procedure under pad conditions.

6.3.2.2.3.2.4 Mission Flow Profile Test. To verify the structural integrity and the ability of the CGSS to supply reactant gases to the fuel cell during static SPS firing.

6.3.2.2.3.2.5 Signal Conditioner Checkout. To verify that the signal conditioners are still in operable condition after shipment from Downey to WSMR.

6.3.2.2.3.3 AFRM-006. AFRM-006 tests are divided into two phases. The first and most important phase is the dynamic (acoustic and vibration) testing of the entire spacecraft. The second phase is the operational testing as a house spacecraft. Due to the hazardous nature of cryogenic fluids, all dynamic tests will be performed with inert test tanks that simulate the actual launch weight and condition.

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ATO tests on AFRM-006 will be conducted at the S&ID facilities at Downey, California, and will include the following tests and test objectives:

6.3.2.2.3.3.1 Electrical Checkout Tests. To verify electrical operability and continuity of the electrically-interfaced components.

6.3.2.2.3.3.2 Dynamic Environment Information Tests. To verify the structural integrity of the CGSS under vibrational and acoustical stress.

6.3.2.2.3.4 AFRM 008. AFRM 008 tests are performed to demonstrate the operational capability of the spacecraft during simulated vacuum and thermal environments. These tests are useful to determine and demonstrate 14-day earth orbital and lunar mission capability. The CGSS is required for AFRM 008 primarily to support the ECS and the F/C in the integrated systems tests. ATO tests on AFRM 008 will include the following:

6.3.2.2.3.4.1 ATO at Downey.

6.3.2.2.3.4.1.1 Leakage Checkout Tests. To verify that the system is not leaking excessively after acceptance by ATO from Manufacturing.

6.3.2.2.3.4.1.2 Electrical Checkout Tests. To verify that the electrical operability and continuity of the electrically-interfaced components.

6.3.2.2.3.4.2 ATO at Houston.

6.3.2.2.3.4.2.1 Service and Checkout Procedure. To prepare the system for vacuum chamber operation.

6.3.2.2.3.4.2.2 Mission Flow Profile Test. To verify that the CGSS has the capability to supply the required flows in a complete S/M - C/M configuration in a space environment, at the required pressure and temperature.

6.3.2.2.3.4.2.3 Signal Conditioner Checkout. To verify that the signal conditioners are still in operable condition after shipment from Downey to Houston.

6.3.2.2.3.5 AFRM 009. AFRM 009 will verify the capability of the spacecraft and subsystem to withstand the launch environment. The vehicle will determine and verify the capability of ground service equipment (GSE) servicing and checkout equipment under actual field conditions. The operation on zero-g environment will be monitored by instrumentation, and will be the first opportunity to observe the operation of the complete working system in a zero-g environment. The purpose of the AFRM 009 CGSS is to form an integrated system with ECS and the F/C.

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ATO tests on AFRM 009 will include the following:

6.3.2.2.3.5.1 ATO at Downey.

6.3.2.2.3.5.1.1 Leakage Checkout Tests. To verify that the system is not leaking excessively after acceptance by ATO from Manufacturing.

6.3.2.2.3.5.1.2 Electrical Checkout Tests. To verify electrical operability and continuity of the electrically-interfaced components.

6.3.2.2.3.5.2 ATO at AMR.

6.3.2.2.3.5.2.1 AMR O&C Building.

6.3.2.2.3.5.2.1.1 L.P. Leakage Check. To verify that the system is not leaking excessively after shipment to AMR.

6.3.2.2.3.5.2.1.2 System Functional Check. To make certain that the system operating components are operable after transport to AMR.

6.3.2.2.3.5.2.2 AMR Cryogenic Test Building

6.3.2.2.3.5.2.2.1 Fuel Cell Operational and Cryogenics Systems Tests. To verify the operational compatibility of the F/C and cryogenic systems.

6.3.2.2.3.5.2.3 AMR C/M - S/M ECS Building

6.3.2.2.3.5.2.3.1 Environmental Control Combined Systems Test. To verify the operational compatibility of the ECS and the CGSS.

6.3.2.2.3.6 AFRM 011. AFRM 011 will be the first manned space flight. This flight will be the first opportunity to verify the operational ability of the CGSS under the critical conditions of service and checkout, launch, zero-g operation of system and instrumentation, and extended manned space flight with the resultant flow demands by the F/C and ECS.

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The quantity probe instrumentation monitoring will be especially critical since it is a sensitive measurement, and it is not known exactly how a zero-g environment will affect the instrument.

ATO tests on AFRM 011 will include the following:

6.3.2.2.3.6.1 ATO at Downey

6.3.2.2.3.6.1.1 Leakage Checkout Tests. To verify that the system is now leaking excessively after acceptance by ATO from Manufacturing.

6.3.2.2.3.6.1.2 Electrical Checkout Tests. To verify the electrical operability and continuity of the electrically-interfaced components.

6.3.2.2.3.6.2 ATO at AMR.

6.3.2.2.3.6.2.1 AMR and O&C Building.

6.3.2.2.3.6.2.1.1 Low Pressure Leakage Check. To verify that the system is not leaking excessively after shipment to AMR.

6.3.2.2.3.6.2.1.2 System Functional Check. To make certain that the system operating components are operable after transport to AMR.

6.3.2.2.3.6.2.2 AMR Cryogenic Test Building.

6.3.2.2.3.6.2.2.1 Fuel Cell Operational and Cryogenics Systems Tests. To verify the operational compatibility of the F/C and cryogenic systems.

6.3.2.2.3.6.2.2.2 Environmental Control Combined Systems Test. To verify operational compatibility of the ECS and the CGSS.

6.3.2.3 S&ID Test Schedule

The test schedule is shown in Figure 6.1.

6.3.3 Power Distribution and Conditioning System

6.3.3.1 Static Inverter

6.3.3.1.1 Objective. S&ID will perform verification tests on the bread-board and prototype versions of the Westinghouse static inverter. This will enable S&ID to determine early in the program if the design is sound and also to design and evaluate proposed circuit variations.

6.3.3.1.2 Test Plan. S&ID will verify the performance of the Westinghouse static inverter in the following areas:

1. To evaluate the transient response of the inverter due to 3-phase shorts, 3-phase overloads, single-phase overloads, step-load changes, and motor starting

2. To determine the efficiency and regulation of the inverter under various load conditions and input voltages.

3. To determine the amount of ripple superimposed on the d-c bus voltages by the inverter under various steady state loads, input voltages, and load changes

4. To determine the effect on the inverter frequency and performance when the synchronizing source is removed from the inverter under normal and abnormal loads

6.3.3.1.3 Equipment and Facilities Required. The equipment and facilities will be provided by the S&ID Engineering Development Laboratories.

6.3.3.1.4 Development Schedules. The development test schedule for the inverter is shown in Figure 6-4.

6.3.3.2 Entry, Post Landing, and Pyrotechnic Batteries.

6.3.3.2.1 Objective. S&ID will perform verification tests on the prototype and qualified versions of the batteries. This will enable S&ID to determine early in the program if the design is sound and compatible with the spacecraft battery charger, battery venting system, and the power distribution system.

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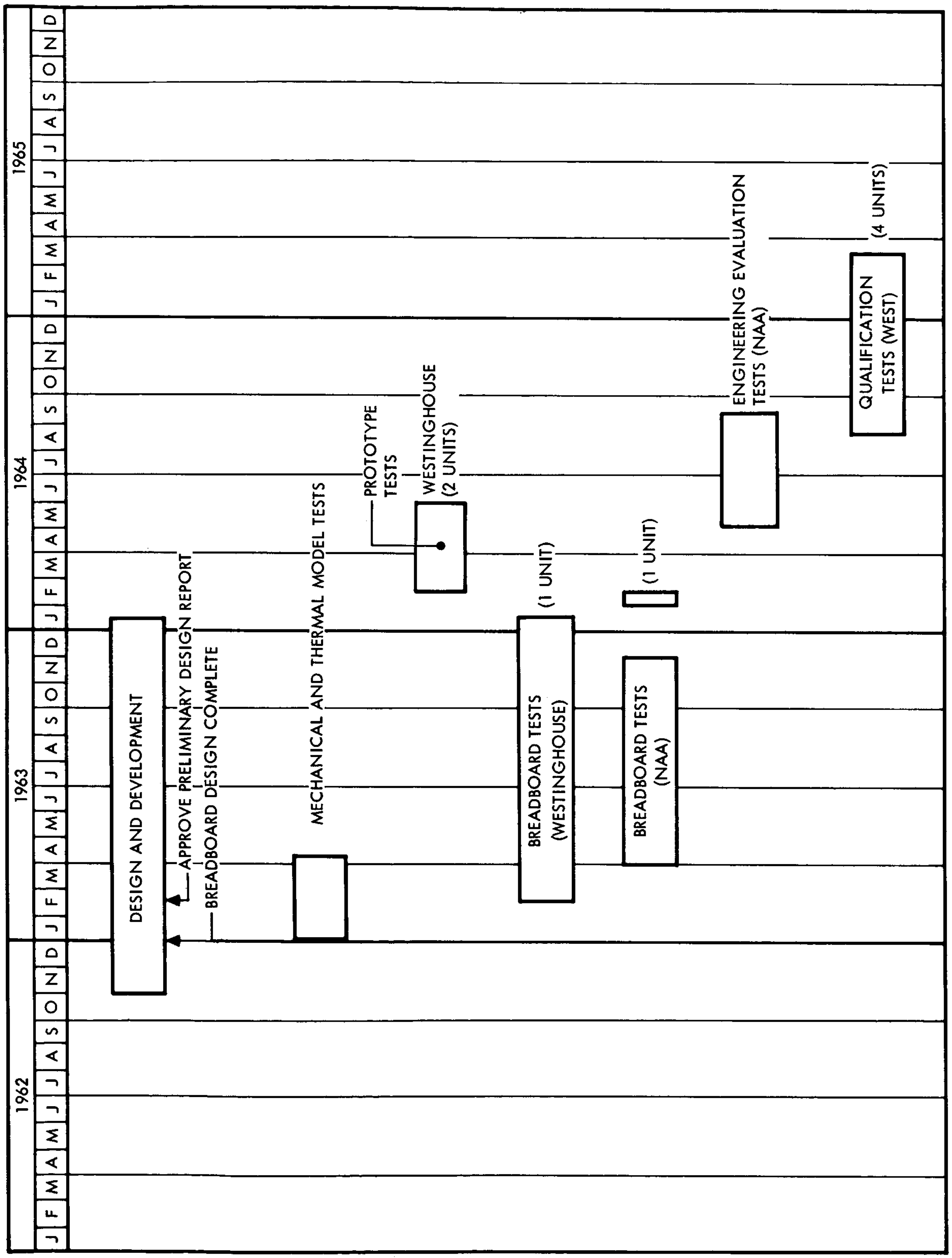

Figure 6-4. Apollo Static Inverter Development Phasing Schedule

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6.3.3.2.2 Test Plan. S&ID will verify the performance of the batteries in the following areas:

1. To evaluate the recharge degradation of the batteries

2. To determine the optimum charging procedure for various states of battery charge. The charging procedure will be determined with ambient temperatures between +50 F and +100 F for the entry and post landing batteries. A charging procedure will be determined for the pyrotechnic batteries to obtain maximum battery capacity prior to vehicle launch.

3. To determine the a-c source impedance of the batteries over the frequency range of 10 cps to 10 KC

4. To determine the ability of the entry batteries to provide sufficient entry power and back-up fuel cell power during midcourse correction maneuvers

5. To determine the ability of the post landing batteries to provide sufficient power after touchdown

6. To determine the ampere-hour capacity versus terminal voltage curves

6.3.3.2.3 Equipment and Facilities Required. The equipment and facilities will be provided by the S&ID Engineering Development Laboratories.

6.3.3.2.4 Development Schedules. The development test schedule for the batteries is shown in Figure 6-5.

6.3.3.3 Battery Charger

6.3.3.3.1 Objective. S&ID will perform verification tests on the breadboard and prototype versions of the ITT spacecraft battery charger. This will enable S&ID to determine early in the program if the design is sound and also to evaluate proposed circuit variations.

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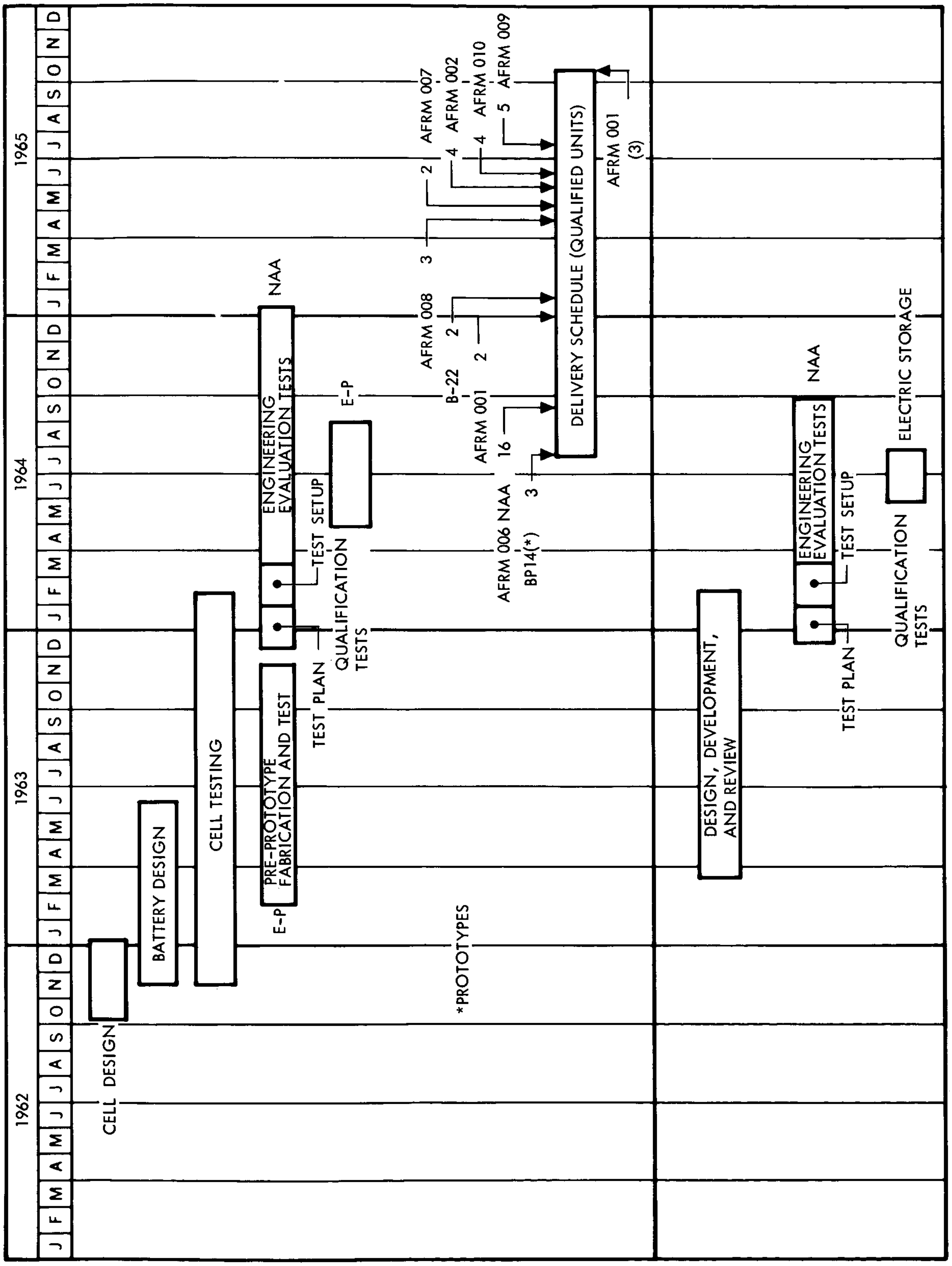

Figure 6-5. Apollo Battery Development Phasing Schedule

[redacted]

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6.3.3.3.2 Test Plan. S&ID will verify the performance of the ITT battery charger in the following areas:

1. To determine the efficiency and regulation of the charger

2. To determine the transient response of unit

3. To evaluate the performance of the battery charger mounted on its coldplate under a vacuum environment with a battery

4. To determine the optimum charging current with respect to time and efficiency, and cut off repeatibility of the battery charger

6.3.3.3.3 Equipment and Facilities Required. The equipment and facilities will be provided by the S&ID Engineering Development Laboratories.

6.3.3.3.4 Development Schedules. The development test schedule for the battery charger is shown in Figure 6-6.

6.3.3.4 A-C and D-C Voltage Sensing Units

6.3.3.4.1 Objective. S&ID development personnel will design and qualify two breadboard voltage sensing units, one for monitoring d-c voltage and one for monitoring a-c voltage. The breadboard approach will enable S&ID to determine early in the program if the designs are sound and also to design and evaluate proposed circuit variations. The Engineering Development Laboratories at S&ID, Downey, California, will perform both the breadboard tests and qualification tests of final hardware. In addition, the electrical power systems compatibility tests will evaluate the performance of the operational components. Some specific objectives of the electrical power systems tests are as follows:

1. To determine the response of both a-c and d-c sensing units to steady-state voltage levels within the intended tolerances of spacecraft power sources

2. To determine the response of both a-c and d-c sensing unit to steady-state voltages below the tolerances of spacecraft power sources

3. To determine the response of both a-c and d-c sensing units to short term over- and under-voltage transients superimposed on normal spacecraft power source voltage levels

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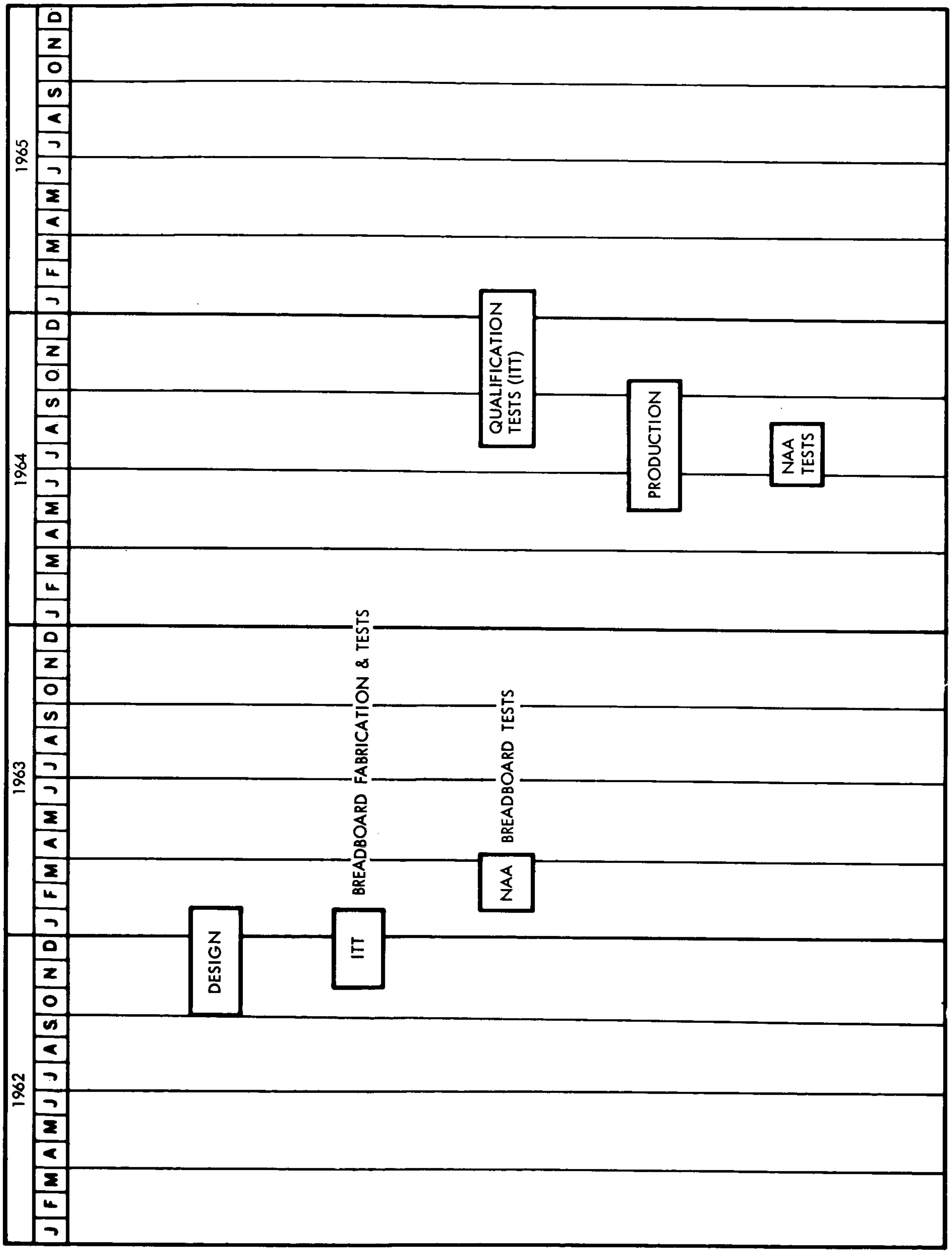

Figure 6-6. Battery Charger Development Phasing Schedule

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4. To determine the response of the a-c sensing unit to steady-state voltage levels above the tolerances of the spacecraft a-c sources

5. To determine the ability of both a-c and d-c sensing units to be reset to their normal mode after having been driven to their respective alarm modes by an out-of-tolerance condition

6. To determine the ability of both the a-c and d-c sensing units to function correctly while operating in environments of temperature excursions above and below those anticipated in actual operation

7. To determine the response of the a-c sensing unit to an overload signal from the inverters

6.3.3.4.2 Test Plan. Breadboard models of the a-c over- and under-voltage sensing unit and the d-c under-voltage sensing unit will be used early in the program. Component parts will be installed in the breadboard models as they are qualified. System compatibility tests utilizing prototype units manufactured by S&ID will prove the design and packaging in its spacecraft configuration.

6.3.3.4.3 Equipment and Facilities Required. The equipment and facilities required will be provided by S&ID Engineering Development Laboratory.

6.3.3.4.4 Development Schedules. The development test schedules for the a-c and d-c sensing units are presented in Figure 6-6.

6.3.3.5 Unmanned Spacecraft Power Programmer

6.3.3.5.1 Objective. S&ID development personnel will design, fabricate and qualify a breadboard power programmer that will be adaptable to all anticipated unmanned spacecraft missions. Primary functions of the programmer will be to accomplish the power switching normally made by an astronaut, both in normal and in emergency modes of operation. The breadboard approach will enable S&ID to determine early in the program if the designs are sound and also to design and evaluate proposed circuit variations as a function of mission profile. The Engineering Development Laboratories at S&ID, Downey, California, will perform both the breadboard tests and

[redacted]

qualification tests of final hardware. In addition, the electrical power systems compatibility tests also will evaluate the performance of the operational components. Some specific objectives of the electrical power systems tests are as follows:

1. To determine the response of the programmer to a d-c low-voltage alarm situation

2. To determine the response of the programmer to an a-c low-voltage alarm situation

3. To determine the response of the programmer to an a-c over-voltage alarm situation

4. To determine the ability of the programmer to disconnect a failed inverter from its input and output mains, connect a spare inverter to the appropriate mains, and start all of the a-c loads involved

5. To determine the capability of the programmer to shut-off fuel cell supplies and disconnect fuel cell electrical loads either in an emergency situation or just prior to C/M - S/M separation

6. To determine the capability of the power programmer to parallel battery combinations during the post-landing period to make maximum use of remaining power capability

7. To determine that maximum switching capability and versatility are combined with minimum power consumption within the power programmer

8. To determine that the programmer will function correctly in spite of the supply voltage variations possible during a malfunction

6.3.3.5.2 Test Plan. A breadboard model of a power programmer that is suitable for a specific unmanned mission will be designed and fabricated early in the program. Component parts will be installed in the breadboard model as they are qualified. System compatibility tests utilizing inverters, batteries, battery chargers, fuel cells, umbilicals and the complete distribution system will provide short-circuit data, overload characteristics, and over-under voltage performance. Prior to house spacecraft tests, electromagnetic interference will be minimized through preliminary analysis and system compatibility tests.

[redacted]

6.3.3.5.3 Equipment and Facilities Required. The equipment and facilities will be provided by S&ID Engineering Development Laboratory.

6.3.3.5.4 Development Schedules. The development test schedules for the unmanned spacecraft power programmer is presented in Figure 6-7.

6.3.3.6 Electrical Power Distribution Subsystem

6.3.3.6.1 Objective. S&ID will verify the performance and component compatibility of the electrical power systems (EPS). The EPS breadboard consists of a number of major components, such as fuel cells or substitute power supplies, solid-state inverters, batteries, charger, and sensing units, and a number of minor components such as motor switches, circuit breakers, diodes, relays, switches, and shunts. These components previously will have been tested individually. The breadboard test will verify the compatibility between components and circuitry in terms of whether the overall EPS will perform in accordance with its design purpose.

6.3.3.6.2 Test Plan. S&ID will evaluate and verify the performance of the breadboard model of the electrical power system in the following areas:

1. Determine transients on the various buses due to overload, short circuits, and step-load changes

2. Determine line, diode, circuit breaker, and bus losses

3. Verify reverse current or power supply unbalance protection

4. Verify fuel cell overload protection

5. Verify specific circuit fault protection; i.e., that the first circuit breaker between fault and power bus trips before a main bus breaker or power supply motor switch

6. Verify proper operation of all bus switching, meter selecting, and voltage sensing circuitry

7. Determine ripple and transients on all buses at various loads and load changes

8. Determine the a-c source impedance of all batteries and fuel cells and buses

9. Verify the proper procedure for transferring from ground power to spacecraft power

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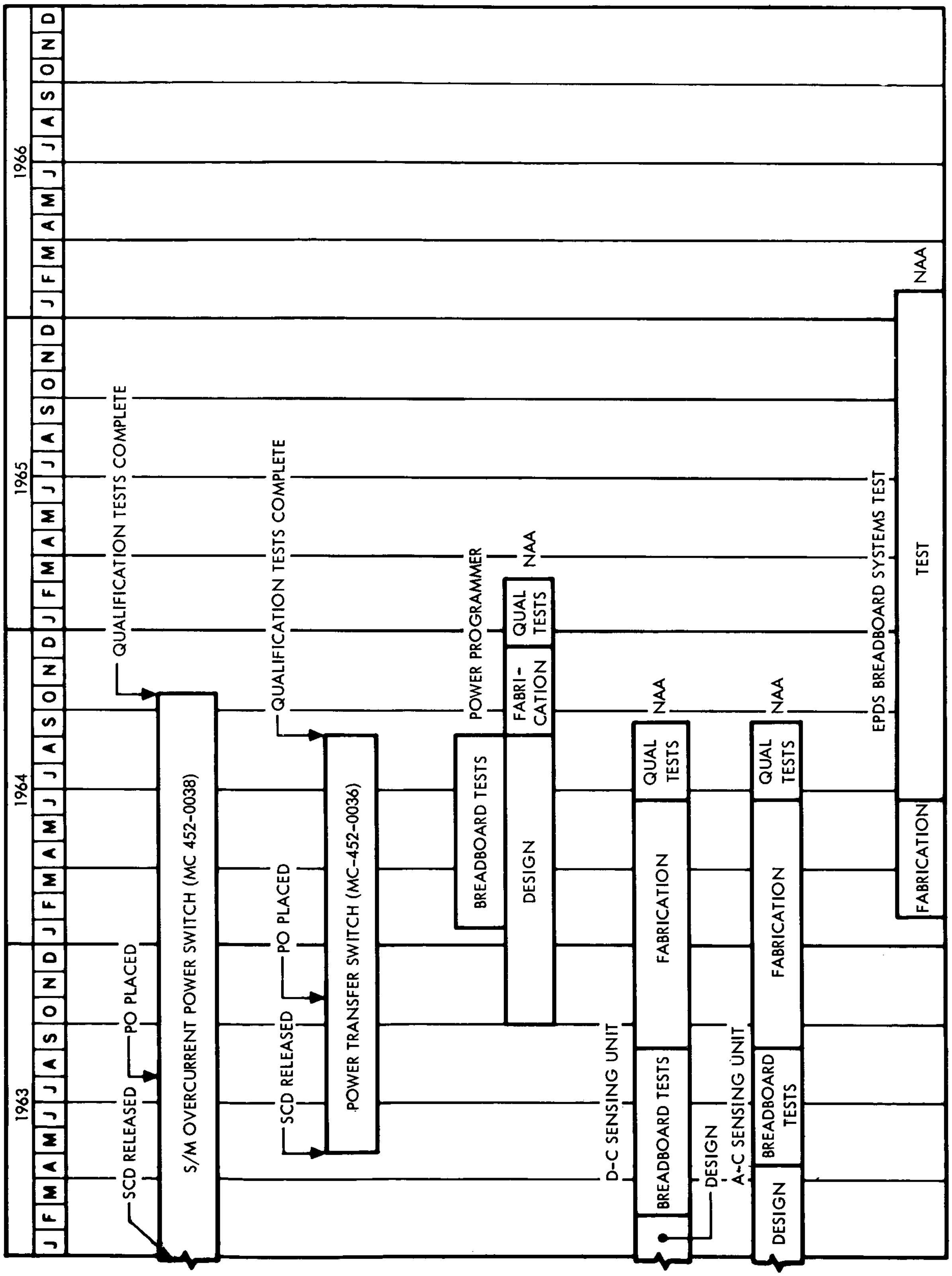

Figure 6-7. Power Distribution and Conditioning System Phasing Schedule

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10. Determine bus transients and verify the procedure for transferring from fuel cell power to battery power

11. Verify the battery energy requirements prior to reentry and during reentry

12. Determine the battery charger operating characteristics under normal and abnormal system operating conditions

13. Determine the operating characteristics of parallel battery and fuel cell operation during simulated midcourse correction (Delta-V) maneuvers

14. Verify the inverter operating characteristics under normal conditions of unbalanced loads and abnormal conditions of shorted output

6.3.3.6.4 Equipment and Facilities Required. The equipment and facilities will be provided by the S&ID Engineering Development Laboratories.

6.3.3.6.5 Development Schedules. The development test schedule for the EPS breadboard test is shown in Figure 6-7.

6.3.4 Electrical Wiring and Equipment System

6.3.4.1 Illumination Subsystem Test

6.3.4.1.1 Objective. The objective of the S&ID tests will be to provide optimum lighting for the Apollo command module with a minimum of power. Specific criteria with regard to choice of components are:

1. Effeciency
2. Power requirements
3. RFI
4. Sealing
5. Cooling

6.3.4.1.2 Test Plan. The test program will determine adequate lighting levels and placement of fixtures. Evaluation testing of the sealed components operating in a hard vacuum will be performed to determine service life, RFI generation, effects of cold-plate mounting, efficiency, and power factor. In addition, the lighting system will be tested for proper operation under the following conditions:

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[redacted] [redacted]

1. High temperature
2. Low temperature
3. Shock
4. Vibration
5. Acceleration
6. Humidity
7. Acoustics

6.3.4.1.3 Equipment. The equipment will be provided by the S&ID Engineering Development Laboratory.

6.3.4.1.4 Schedule. The development schedule for the illumination subsystem is presented in Figure 6-8.

6.3.4.2 Distribution Subsystem Test

6.3.4.2.1 Objective. S&ID tests of distribution subsystem components for boilerplates will be minimal. Qualified relays, diodes, fuses, circuit breakers, wires, and cabling will be utilized, whenever possible. Prototype subsystem components will be qualified in accordance with Apollo requirements.

In addition, effort will be expended toward accomplishment of the following objectives:

1. To standardize relays, circuit breakers, etc., where possible
2. To optimize reliability
3. To verify capacity of system and minimize losses

6.3.4.2.2. Test Plan. An extensive test program will be required to qualify components utilized in prototype spacecraft. Tests will be designed to establish the high order of reliability required of Apollo. Breadboard models of the distribution subsystem will be utilized early in the program, and component parts will be installed in the breadboard models as they are qualified. In this manner, the distribution and control portion of the EPS will have been tested thoroughly prior to prototype delivery of the subcontracted major components.

6.3.4.2.3 Equipment. This equipment will be provided by the S&ID Engineering Development Laboratory.

6.3.4.2.4 Schedule. The development schedule for the distribution subsystem is presented in Figure 6-9.

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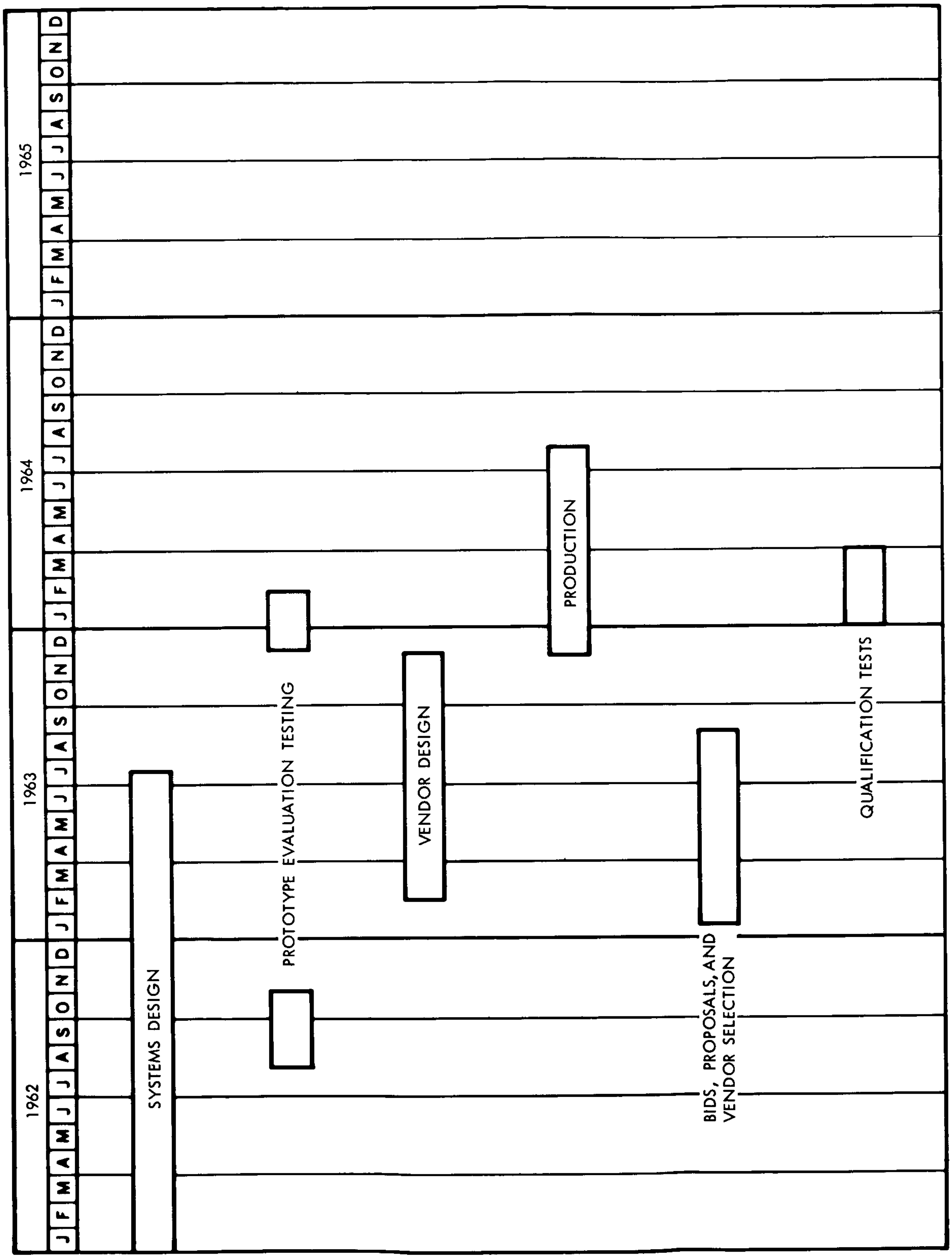

Figure 6-8. Preliminary Illumination Subsystem Development Phasing Schedule

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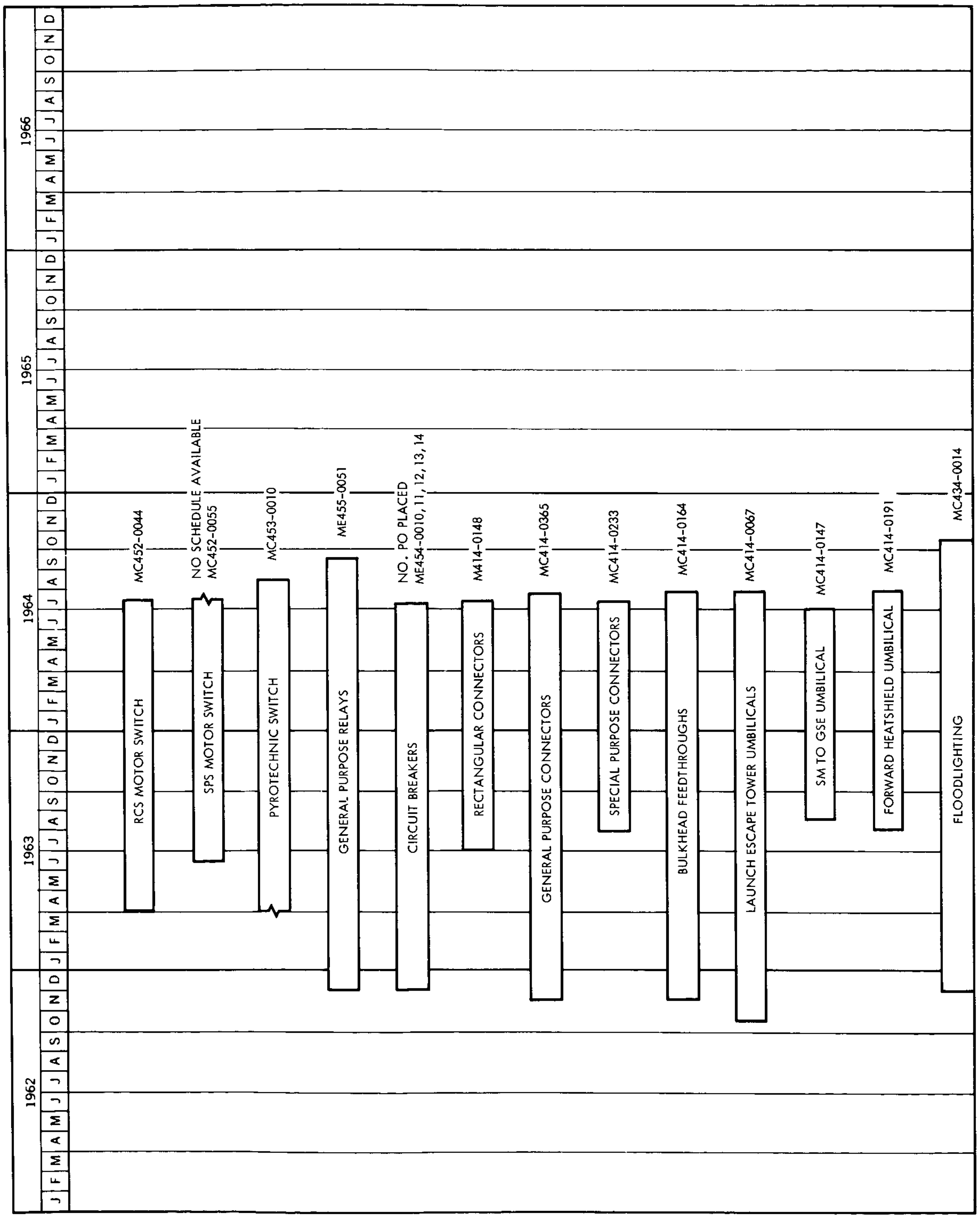

Figure 6-9. Preliminary Electrical Wiring and Equipment Development Phasing Schedule

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7.0 GUIDANCE AND NAVIGATION SYSTEM

7.1 SCOPE

Efforts concerning the development, design verification, evaluation, qualification, and reliability testing of the guidance and navigation subsystems, and systems are specifically divided between the associate contractor and S&ID. The test programs conducted by the associate contractor and S&ID will be integrated to avoid redundancy and to provide maximum confidence level in the success of the end requirement, lunar orbit and return.

7.2 ASSOCIATE CONTRACTOR TEST PLAN

The Massachusetts Institute of Technology (MIT) test plan is negotiated between MIT and NASA. Consequently, it is not a part of this test plan.

7.3 S&ID TEST PLAN

7.3.1 Objectives

The S&ID test plan is being completely rewritten and will be included in the 30 September 1964 revision.

[redacted] [redacted]

8.0 STABILIZATION AND CONTROL SYSTEM*

8.1 SCOPE

Development, design verification, evaluation, prequalification, and acceptance testing of the stabilization and control components, subsystems, and systems will be done jointly by the subcontractor and prime contractor. Only the engineering development, evaluation, and design verification tests are outlined herein. Qualification test plans will be reported in Volume III.

8.2 SUBCONTRACTOR TEST PLAN (MINNEAPOLIS-HONEYWELL)

8.2.1 Objectives

The stabilization and control test plan includes the development and design verification testing of the stabilization and control system (SCS).

The test plan is designed to allow a smooth transition between the various development stages. Over-all end requirements (lunar orbit and return) will be met on the hardware intended for the final phase by progressively increasing the severity of the environments.

8.2.2 Test Plan

The types of tests to be conducted on the prototype SCS include circuit development, component development, system development, system breadboard, computer simulation, radio interference environmental evaluation, design improvement, and acceptance tests.

8.2.2.1 Stabilization and Control System

The SCS consists of the following subsystems:

1. Attitude gyro, accelerometer package (AGAP)
2. Pitch channel electronic control assembly (pitch ECA)
3. Roll channel electronic control assembly (roll ECA)

*Entire section reissued

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[redacted]

4. Yaw channel electronic control assembly (yaw ECA)
5. Auxiliary electronic control assembly (auxiliary ECA)
6. Display electronic control assembly (DECA)
7. Translation control
8. Three-axis rotation control
9. ΔV display
10. Attitude set - gimbal position display (ASGPD)
11. SCS control panel
12. Flight director attitude indicator (FDAI)
13. Rate gyro package (RGP)

8.2.3 Developmental Test Plan

One engineering functional breadboard model of each subsystem will start development testing. Four subcontractor in-house prototype SCS will be used for prequalification and design-improvement testing.

The subcontractor's test plan organization is catagorized as follows:

1. Materials test
2. Component test
3. System test
4. Acceptance test

8.2.3.1 Materials Testing

To comply with the SCS procurement specification with respect to material and process selection, Honeywell plans to conduct an organized program of material review and evaluation. This program will be conducted in two parts, a general materials review and approval procedure in close support of the equipment design, and an investigative program directed specifically at determining the suitability of materials for use in the SCS with respect to several special properties.

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8.2.3.1.1 General Materials. Selection of a list of materials and processes likely to be used in the design of the SCS controls and displays. This list will be limited to those materials and processes which have been used in similar equipments.

8.2.3.1.2 Special Material Properties. Those material properties specified in the SCS procurement specification for which no information is available will be evaluated as part of the special properties investigation.

8.2.3.2 Component Test

This section is divided into four test areas. These areas are:

1. Part design margin tests

2. Circuit development tests

3. Electromechanical development tests

4. Prequalification tests

8.2.3.2.1 Part Design Margin Tests. These tests consist of subjecting parts to incremental increases of electrical or environmental stresses beyond qualification limits. This is accomplished while significant performance parameters are monitored until failure (including out-of-tolerance condition) occurs, or a predetermined stress level is reached.

Concurrent with the development phase of the program, these tests will be conducted on parts whenever required for completion of a failure analysis to verify that the part is suitable for Apollo applications. Application suitability will be assured through the following means:

1. Determination and evaluation of failure modes

2. Verification of Honeywell and vendor derating criteria

Part design margin tests will also be conducted by the part vendor or by Honeywell during part qualification testing. In all cases, existing test and experience data will be reviewed prior to conducting qualification or part design margin tests in order to minimize the amount of testing required without compromising the program intent.

8.2.3.2.2 Circuit Development Tests. The circuit development test phase is organized as follows:

1. Circuit concept and operation verification

[redacted]

2. Parts suitability, compatability, and reliability

3. Parameter variation analysis

Variable parameters include line voltage, temperature, inputs, and end part tolerances. These analyses will determine the following:

1. If circuit performance is within specification

2. If stresses on parts are within part ratings.

The analyses are performed either empirically with breadboard circuits or analytically with mathematical models and computer techniques.

8.2.3.2.3 Electromechanical Tests. Breadboard and mockup testing of the electromechanical packages during the developmental test phase falls generally into two interrelated categories, conceptual and environmental.

1. Conceptual developmental tests will be conducted on mechanisms, configurations, and piece parts to determine if ideas and methods appear feasible in practice to accomplish an intended purpose.

2. Environmental development tests will be conducted on electromechanical breadboards and mockups to obtain engineering data under selected environmental conditions.

Structural integrity tests during design development will be conducted to confirm analytical studies and to provide design data for cases which do not lend themselves to analytical solutions.

8.2.3.2.4 Prequalification Tests. During this phase, design proof tests will be conducted on the final configuration of the components. Early testing of the SCS components to temperature, altitude, vibration, shock, acoustic noise, and electromagnetic interference will be accomplished. Engineering judgment will be used to determine the test duration on an individual component basis to reasonably guarantee compliance with the final design proof requirements. The primary objective of these tests will be to establish early assurance that the formal qualification tests will be successful.

8.2.3.3 System Test

The purpose of the systems verification program is to prove the design of the SCS as it evolves in a room temperature environment providing for confidence that the SCS will meet performance requirements in the specified

[redacted]

qualification environment. This program includes the simulation and test activity associated with the verification of selected component parameters to meet system performance requirements.

The design verification program consists of the simulation and test of the closed loop SCS design in three phases:

Phase I: Analog or hybrid computer tests in which the SCS is simulated entirely on the computer in conjunction with the vehicle equations of motion.

Phase II: Analog or hybrid computer tests in which the SCS components are introduced, in part or in total, to the computer tests, in conjunction with the vehicle equations of motion. Where controls and displays are introduced into the simulation, the augmented continuous control evaluator (ACCE) will be utilized. If sensors are introduced to the simulation, peripheral dynamic equipment which forms a part of the ACCE will be utilized.

Phase III: Simulations combining the concepts of Phase I and Phase II and utilizing peripheral dynamic equipment to incorporate SCS sensors into the closed loop. Phase III consists of verifying system hardware performance utilizing the verification test model SCS in a test environment which includes all the elements of the ACCE and ACE, respectively, and includes the pilot (Figure 8-1). This phase will also include dynamic closed-loop tests on the air-bearing table (Figure 8-2) using actual sensors, displays, and simulated output devices.

8.2.3.4 Acceptance Tests

The minimum acceptance-test operating time is 100 hours. (Minimum operational time is defined as system operating time not including prior operating time accrued by individual components. The last ten hours of system operation must be failure-free.)

There are two significant phases to the acceptance procedures and implementation that will be established and conducted by Honeywell for the delivery of SCS hardware to NAA. These phases are:

Phase A: Acceptance testing of the first four SCS's manufactured, functional models "A", "B", "C" and No. 1 flightworthy

[redacted]

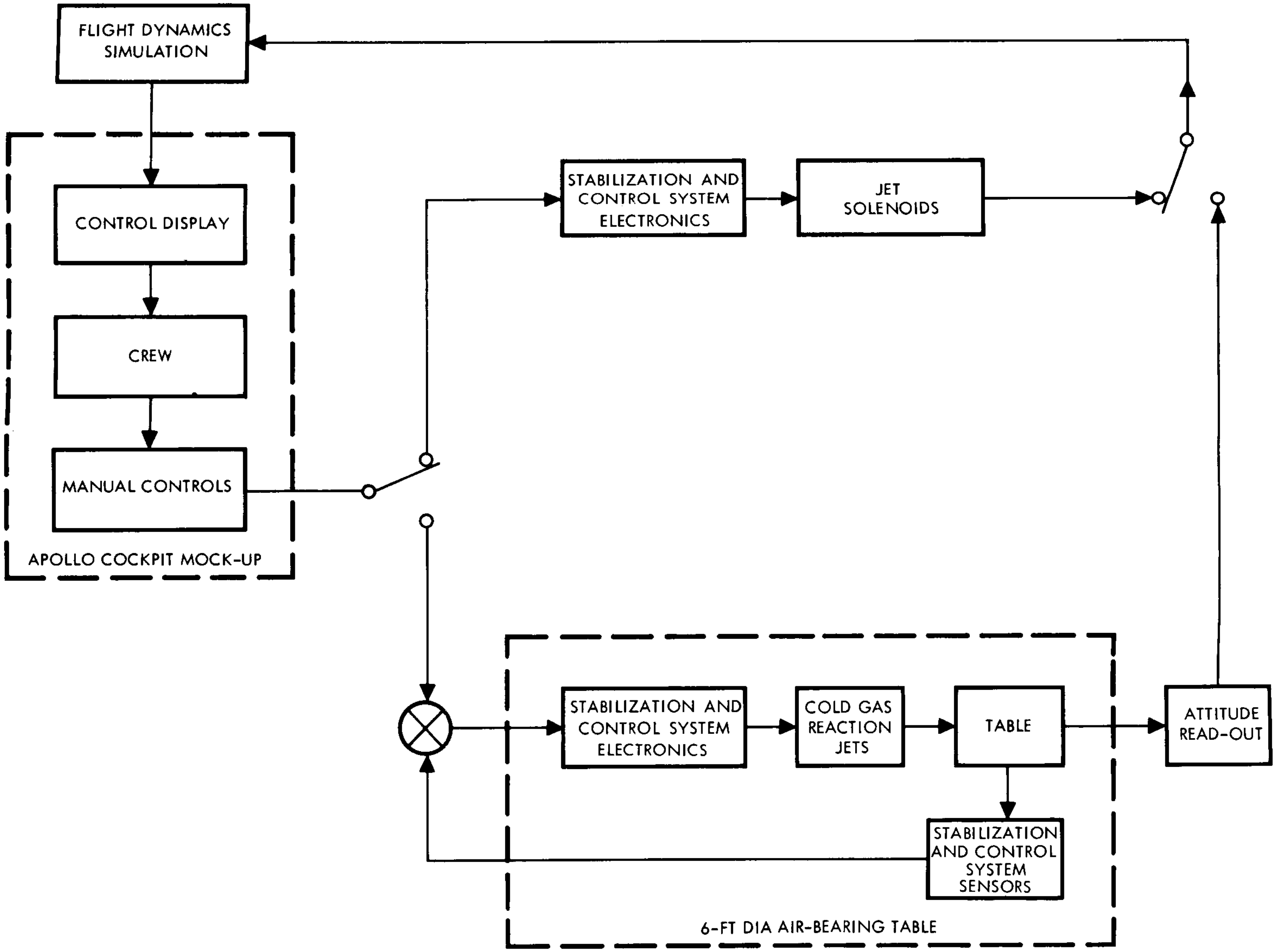

Figure 8-1. Apollo Augmented Continuous Control Evaluator

[redacted]

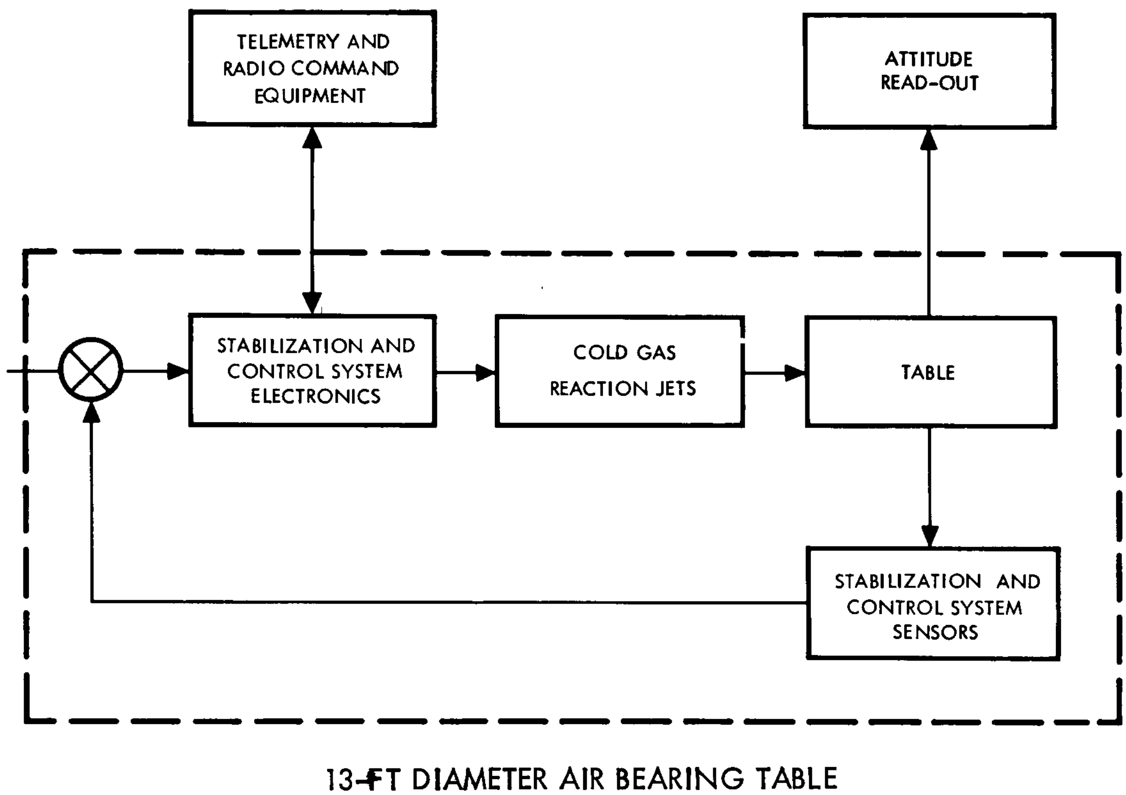

Figure 8-2. Apollo Dynamic Attitude Control Simulator

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Phase B: Acceptance testing of all subsequent SCS's manufactured and denoted on SK 80721-17, dated 5 December 1962.

8.2.3.4.1 Phase A - Acceptance Testing. During this initial phase of acceptance testing, the SCS hardware, acceptance procedures, and final performance requirements will be developed and approved. For these processes to be accomplished on a sound engineering and quality basis and also to be conducted economically, the following program will be conducted on the first four SCS's fabricated. These systems are functional "A" and No. 1 flightworthy retained by Honeywell, and functional "B" and "C" delivered to NAA.

8.2.3.4.2 Phase B - Acceptance Testing. This phase is intended to become the developed and approved acceptance testing procedure and implementation for all SCS's delivered on the contract after the initial four SCS's are delivered as outlined in Phase A.

8.2.4 Radio Interference Tests

Radio interference (RFI) tests will be conducted on the completed subsystems, and will be based on familiarization studies of the system, predictions of interference areas, and problems encountered during design and development phases. Additional filtering and/or repackaging will be completed prior to system testing, and based upon results of the preceding testing. RFI tests will be conducted at the system level, and additional filtering and repackaging incorporated where, as a result of system level testing, it is deemed necessary.

8.2.5 Environmental Tests

Testing will be done on basic materials, components, subsystems, and under environmental limits throughout the entire program, with the end results compatible with lunar mission and return requirements. Subsystem testing will be conducted in two phases.

8.2.6 Equipment

1. Shock tester
2. Vibration shock, acceleration holding fixture
3. RF noise generators (to 5.4 kmc)
4. C-25 vibration machine
5. C-125 vibration machine

[redacted]

6. Air-bearing table (6 feet diameter, 400 slug-feet^2)

7. Miscellaneous test instrumentation

8. GSE

9. Air-bearing table (13 feet diameter, 25,000 slug-feet^2)

8.2.7 <u>Facilities</u>

1. High-low temperature chamber

2. Altitude temperature chamber (10^6 mm Mg)

3. Radio screen room

4. Explosion-proof chamber (100 percent O_2 at 5 psia)

5. Acoustic noise chamber

6. Environmental test chamber

8.2.8 <u>Test Schedule</u>

For the test schedule refer to Figure 8-6 at the end of this section.

8.3 S&ID TEST PLAN

8.3.1 <u>Objective</u>

Prime contractor's tests will augment the subcontractor's test program with design verification and evaluation testing that will explore the complete S&C system and combined systems problems. Emphasis will be on all major interface areas encountered in the spacecraft.

8.3.2 <u>Test Plan</u>

The types of tests to be conducted on the prototype SCS include subsystem evaluation, subsystem interface evaluation, system evaluation, and analog/hardware simulation tests. The test setups, techniques, and general approach will be different from those used by the subcontractor, so that these tests can serve as an effective verification of the subcontractor's test results.

[redacted]

8.3.2.1 Subsystem Evaluation Tests

These tests will be performed on all major elements of the stabilization and control systems in the prime contractor's engineering laboratories. Inertial devices will be tested to determine transfer functions, linearity, scaling, resolution, deadband, torquing accuracies, null shift characteristics, etc. Semiconductor modules such as signal amplifiers, power amplifiers, demodulators, etc., will be thoroughly tested to determine gain characteristics, nonlinearities, effects of noise, effects of power supply variations, etc. Power supplies will be tested to determine regulation characteristics, output wave form characteristics, effects of variations of source power, and possible malfunction modes and their effects on over-all system operation.

8.3.2.2 Subsystem Interface Evaluation Tests

Subsystems, such as engine gimbal servo loops and reaction-control logic, will be tested in conjunction with their interface systems or system components to determine and verify compatibility, effects of in-design and off-design tolerance excursions, combined systems transfer functions, deadbands, nonlinearities, etc. Reaction-control logic schemes will be breadboarded and compared in a single degree of freedom sense for tradeoffs in energy management, deadband size, minimum realizable vehicle rates, etc., in conjunction with an analog computer. Engine-gimbal servo loops will be tested statically and dynamically with various loads applied and under actual firing conditions at the WSMR.

8.3.2.3 System Evaluation Tests

Complete prototype SCS will be tested in the engineering laboratories to determine, verify, and evaluate system parameters and characteristics, compatibility with interface systems and GSE, interchangeability, effectiveness of checkout procedures, malfunction mode analysis, error analysis verification, effects of variations of power systems, and compatibility with the manual controls and displays.

8.3.2.4 Analog/Hardware Simulation Tests

Comprehensive evaluation testing of the stabilization and control system, using the analog computer to close the outer loop around the portion of the system being tested, will be conducted as breadboard and prototype hardware become available. This portion of the test program will investigate the effects, hardware nonlinearities, associated variations on margins of stability and limit-cycle characteristics for various flight modes, and investigate system interaction and effectiveness when undergoing simulated flight conditions.

[redacted]

Because of the lead times involved in procuring engine system components, flight tables, etc., the analog/hardware simulation tests will be divided into phases.

Phase I will consist of pure synthesis of control problems in which stability and control system hardware as well as vehicle parameters will be simulated on the analog or digital computer. During these studies, stabilization and control hardware characteristics will be represented as accurately as known within the capability of normal programming. The results of these studies will be the basis of the functional system design and hardware development and fabrication.

Control electronics hardware will be tested in conjunction with the analog computer. In these early simulations, vehicle dynamics, sensor dynamics, valve and engine dynamics, gimbal actuator dynamics will be simulated on the computer, and only the control electronics will be used to complete the loop outside the computer.

Phase II tests will serve as a means of determining and evaluating the effects of the hardware characteristics of the control electronics portions, of the system. All flight modes will be studied and new computer programs will be written to include mechanization of those nonlinearities, discontinuities, etc., determined to be significant.

A block diagram of the Phase II test configuration is shown in Figure 8-3.

Phase III will be similar in intent to Phase II simulation tests, except that reaction-control engines and engine-gimbal actuators will be added to the hardware in the loop outside the computer.

Load simulators will be utilized, if required, to load engine-gimbal actuators, and engine geometric center-line position (representative of thrust-vector position) will be instrumented if engine-actuator-structure compliance is determined to be a problem.

A block diagram of the Phase II test configuration is shown in Figure 8-4.

The intent of Phase IV will be similar to that of Phases II and III, except that angular inertial elements will be placed on a flight table driven by vehicle angular rates as determined by the computer.

A block diagram of the Phase IV test configuration is shown in Figure 8-5.

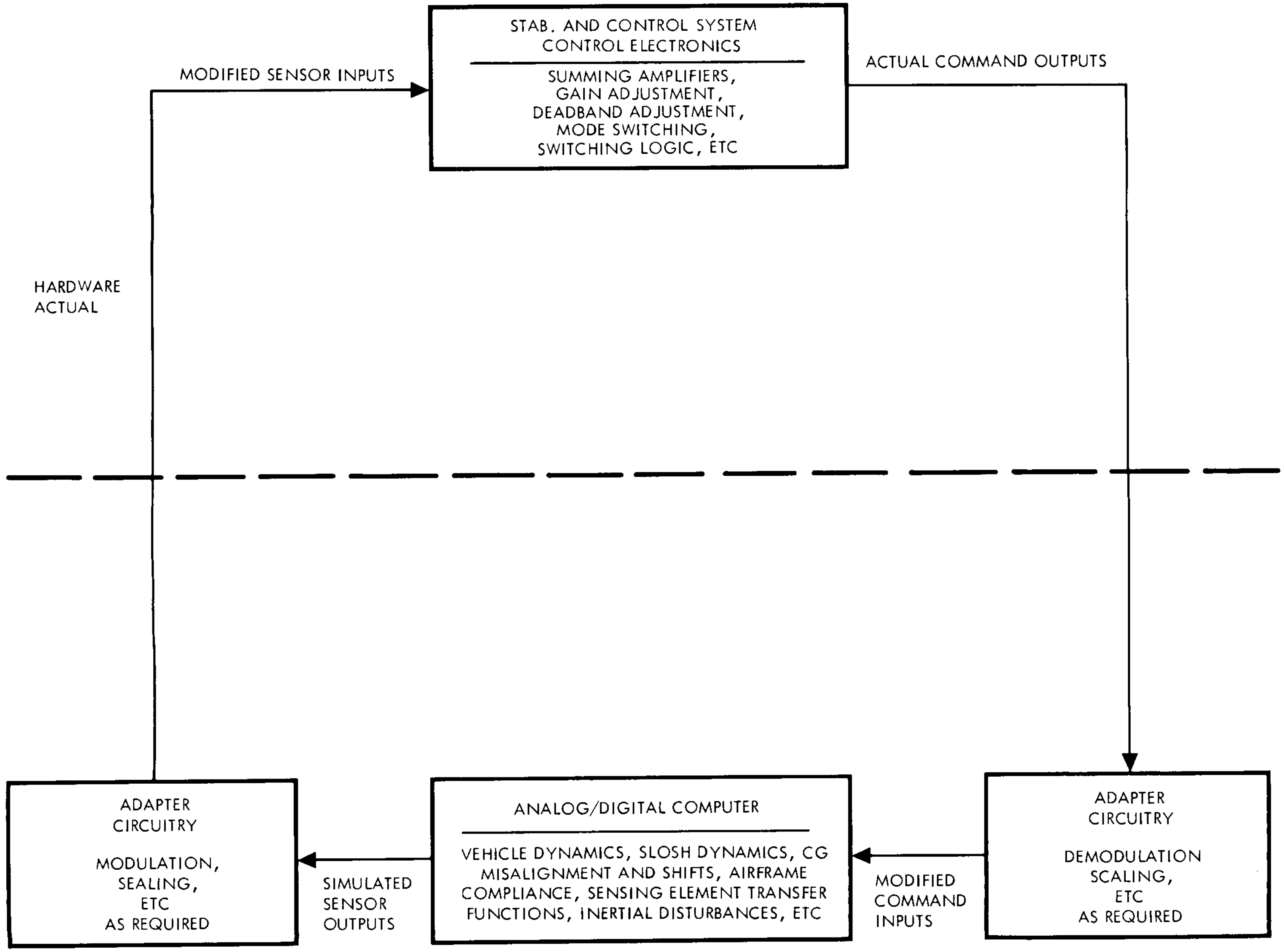

Figure 8-3. Phase II Test Configuration

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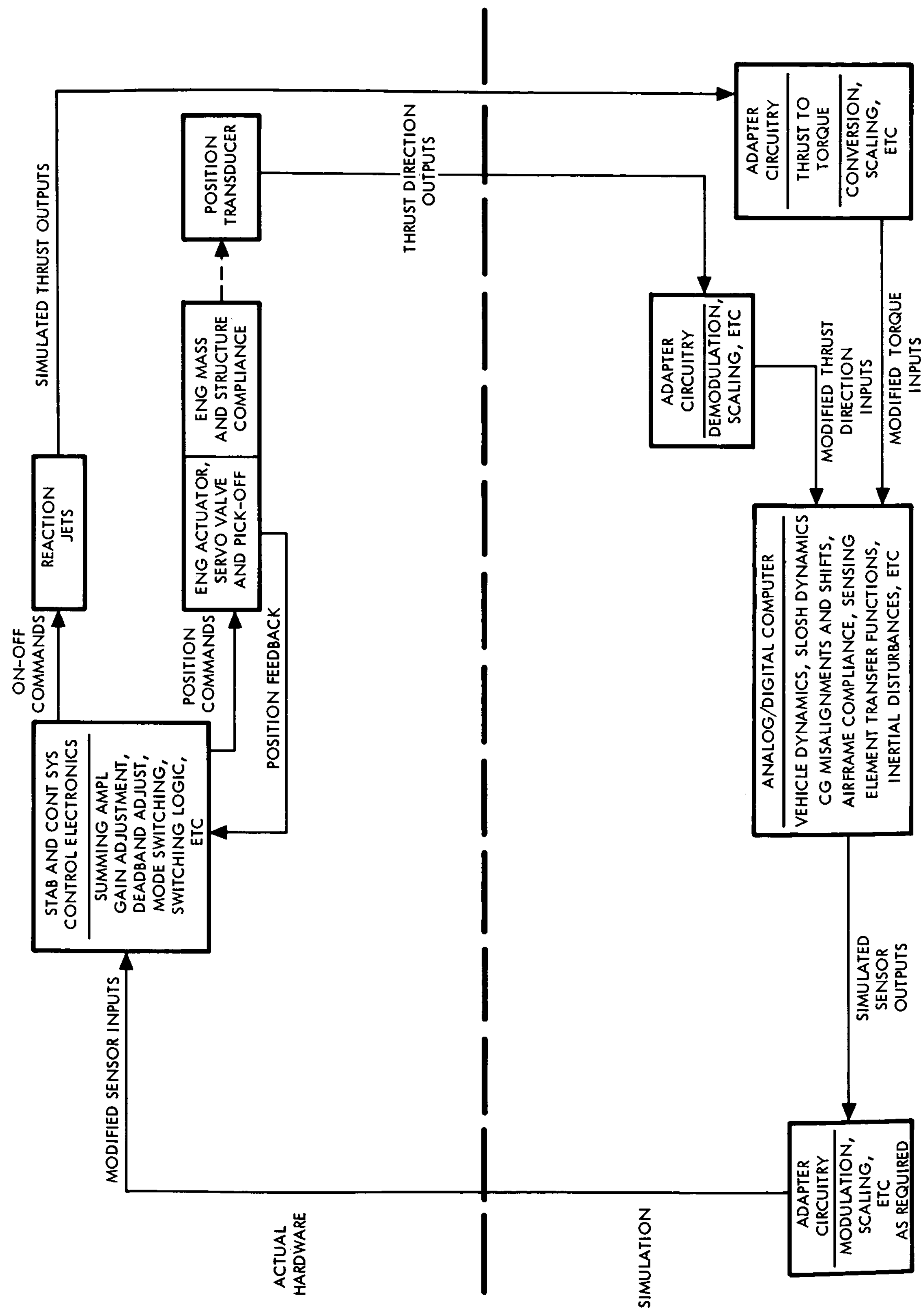

Figure 8-4. Phase III Test Configuration

[redacted] [redacted]

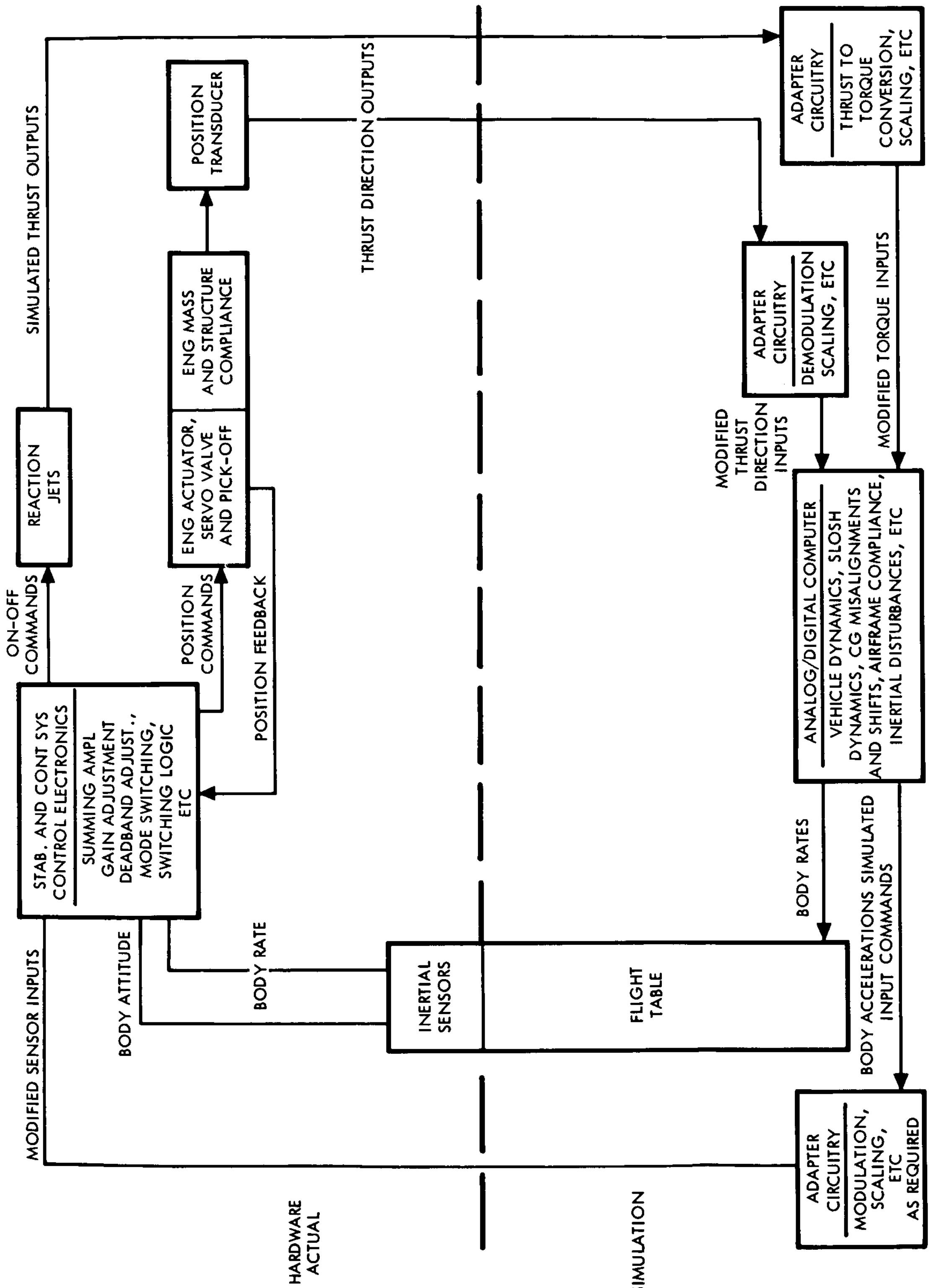

Figure 8-5. Phase IV Test Configuration

8.3.3 Equipment

Dividing head (Leitz)

Rate table (Genisco C-181)

Flight table (to be determined)

GSE

Miscellaneous instrumentation

8.3.4 Facilities

The guidance and control system laboratory and the analog-digital computer will be used.

8.3.5 Schedule

A schedule of R & D test activity is shown in Figure 8-6.

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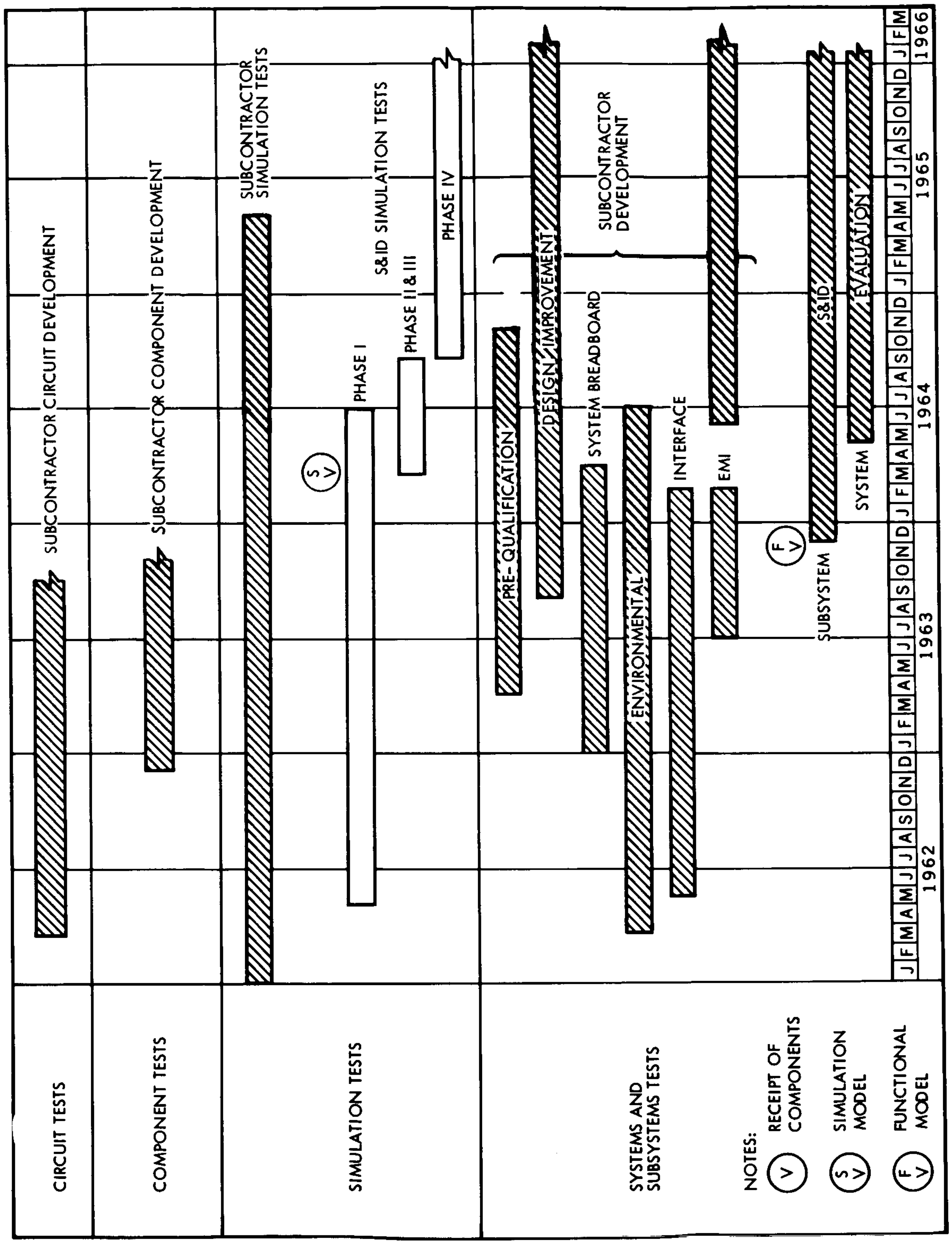

Figure 8-6. Stabilization and Control Test Schedule

[redacted]

9.0 COMMUNICATIONS AND INSTRUMENTATION SYSTEMS

9.1 SCOPE

The subcontractors will perform development, design verification, qualification, and acceptance tests. The major subcontractor (Collins Radio) will also perform systems-type tests on one set of prototype equipment of that portion of the communications system which is covered by the Collins subcontract. S&ID will verify specified equipment, perform evaluation tests on the complete communications system, and explore interface problems. Development, qualification, and acceptance tests will be performed on the S&ID fabricated antennas, and the 2-KMC high gain antenna will be calibrated and aligned. Detailed equipment tests will be performed by using bench maintenance equipment necessary for performance verification and maintenance. Spacecraft-GOSS compatibility tests will be performed. Only the engineering development, design verification, antenna pattern, evaluation, calibration and alignment tests will be described in this section. Qualification and acceptance test plans will be reported in SID 62-109-3 and SID 62-109-4.

9.2 SUBCONTRACTOR TEST PLAN

9.2.1 Objectives

The objectives of the subcontractor's tests are to establish the feasibility of the design approach and to develop the design in accordance with design specifications, to operational maturity.

9.2.2 Test Plan

9.2.2.1 Major Subcontractor (Collins Radio)

The major subcontractor and the second tier subcontractors will conduct an extensive test program during the design and development of the equipment. The test program will consist of spacecraft equipment tests, to ensure compliance with the equipment specifications, and subsystem tests by the major subcontractor. The tests will be performed on one complete set of E-model equipment of that portion of the communications system which is covered by the Collins subcontract. The equipment consists of the following:

VHF-FM transmitter
VHF-AM transmitter-receiver
Unified S-band equipment (second tier subcontractor-Motorola)
S-band power amplifier
C-band transponder (second tier subcontractor-ACF)
VHF recovery beacon
HF transceiver
Audio center
Premodulation processor
PCM telemetry (second tier subcontractor-Radiation)
Signal conditioning equipment
Data storage equipment (second tier subcontractor-Leach)
VHF multiplexer
R&D VHF omni-antenna equipment (See Paragraph 9.2.2.1.4.)

The major subcontractor's equipment will be defined by the extent of the tests that it has succuessfully completed and by its use, as defined below:

E-Model. The equipment will be in the final package configuration, and will incorporate design changes resulting from developmental testing. All design verification tests will be conducted on this model to upgrade the design to a status that is expected to pass qualification tests.

D-Model. This equipment will incorporate changes resulting from the design verification tests and will contain high reliability components. Qualification tests will be performed on this model.

P-Model. This equipment will incorporate all design modifications resulting from the qualification program, as well as any changes from the design verification test program obtained after D-model design freeze. This model will be considered qualified for use on manned missions.

9.2.2.1.1 Development Tests. Development tests will be performed early in the design phase on equipment, modules, circuits, and components to determine the feasibility of the circuit design, mechanical design, and component application. The tests primarily are electrical, but some modules and equipment mock-ups will be subjected to thermal and vibration environments to determine their performance under these conditions. All developmental tests will be performed by the design engineers of the major subcontractor or the second tier subcontractor. Electrical tests will be made on breadboard circuits and the results will be used to verify the performance required, or to indicate where changes in the circuitry are needed. In many cases, after the electrical design has been established with the breadboards, a brassboard model will be built. In this model, the components will be packaged in a manner similar to the expected final configuration. Electrical, exploratory thermal, and vibration tests will be made on the brassboards to obtain information on the effects of the placement of components on electrical, thermal, and vibration characteristics. The E-model design will be established using information obtained from development tests.

9.2.2.1.2 Design Verification Tests. The design verification tests will determine the capability of the equipment to meet operational performance requirements when subjected to selected environments. These tests will include preliminary design proof tests, off-limits tests, and parts application tests. All design verification tests will be conducted by the manufacturer of the equipment; that is, the major subcontractor's second tier subcontractor will conduct all design verification tests on its equipment. A typical time phasing of the design verification test program is shown in Figure 9-1.

9.2.2.1.2.1 Preliminary Design Proof Tests. Preliminary design proof tests will be performed on two early E-models of each equipment by the major subcontractor's, or the second tier subcontractor's, design engineers. The tests will include functional tests under laboratory conditions and normal line voltage, high and low line input voltage tests, environmental tests, and electromagnetic interference (EMI) tests. The objectives of the preliminary design proof test are to evaluate high and low line functional operation; to demonstrate the capability of the equipment to operate under service conditions as specified in MC999-0023, General Specification for Communications and Data Subsystem; and to demonstrate the equipment compliance with the EMI requirements, as specified in MC999-0023. The changes resulting from the functional tests, vibration, and high-temperature tests will be incorporated in the D-model design. All modifications resulting from information obtained from tests occurring after the D-model design freeze will be incorporated into the P-model design.

9.2.2.1.2.2 Part Application Tests. The objective of part application tests is to verify proper part selection and application within the equipment. These tests will determine the factor of safety in part applications with respect to the applicable part parameters, related part specifications, and specified part derating principles. The tests will be conducted on one E-model of each piece of equipment, and will consist of measuring electrical, thermal, and mechanical stresses on parts in their respective applications. Electrical stresses, including voltage and/or current and transient conditions, will be measured on parts during equipment operation under nominal conditions. From the electrical stress measurements and design analysis, temperature critical parts will be determined and the thermal stress on

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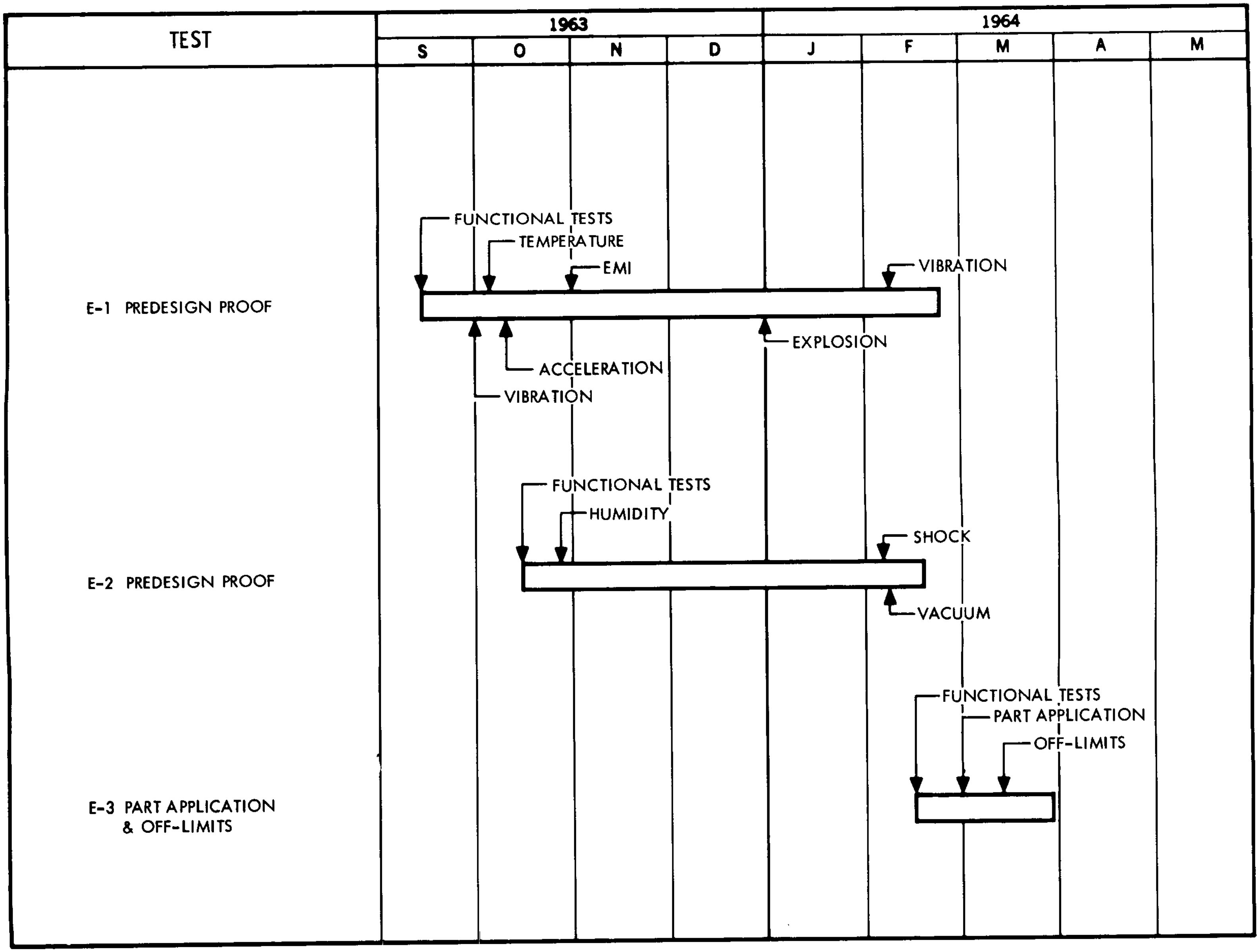

Figure 9-1. Major Subcontractor Typical Design Verification Tests

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[redacted]

these parts will be measured. Mechanical stresses, deemed critical by design analysis, will be measured on selected electrical, mechanical, and electro-mechanical parts. The information obtained from part application tests will be incorporated into the P-model design.

9.2.2.1.2.3 Off-Limits Tests. Off-limits tests will be conducted on the same unit used for part application tests after the part application tests have been completed. The objective of off-limits tests is to determine the equipment design margin of safety early in the test program. Each equipment will be subjected to increasing environmental and electrical stress levels beyond the design proof levels until a significant output degradation of the equipment occurs and no further useful performance information can be obtained.

The off-limits test stresses to be investigated during the design verification tests will include combined temperature-voltage, combined random-sine-wave vibration, and shock. The information obtained from these tests will be incorporated into the P-model design.

9.2.2.1.3 Subsystem Tests. A subsystem test will be performed by the major subcontractor to assure compatibility between individual equipment and satisfactory operation as a subsystem. The tests will be performed on one complete set of E-model equipment for which the major subcontractor is responsible. They will consist of electrical integration tests and EMI tests. No environmental tests will be conducted at the subsystem level. The tests will be performed first at the open-system bench test level. The equipment will be connected by a system wiring harness around the test area, and the tests will be conducted in a spacecraft mock-up with a simulated lower equipment bay. The advantage of the open-system bench test is that preliminary problems can be solved away from the confined area of the lower equipment bay. The capsule tests provide a subsystem simulation with the actual spacecraft wiring harness and the equipment installation rack. The information obtained from the subsystem test will be used in the P-model design.

9.2.2.1.4 R&D VHF Omni-Antenna Equipment Test Programs. The R&D VHF omni-antenna equipment program will not be as sophisticated as the test program on other equipment supplied by the major subcontractor. The reason is that this antenna equipment is used only on unmanned R&D missions, and will not see the stringent environments and duty cycles that the other major subcontractor supplied equipment will experience on lunar missions. Development tests will be conducted on the antenna and will consist of electrical tests on both scaled and full-scale models. The purpose of the tests will be to determine the optimum physical shape of the antenna that will provide electrical characteristics to meet the performance requirements specified in MC481-0026, Specification for the R&D VHF Omni-Antenna Equipment.

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9.2.2.2 Antenna Subcontractors

The subcontractors supplying antenna equipment will conduct an extensive test program during the design and development of the equipment. The tests will include model antenna patterns, full-scale patterns, and development and design verification. The antenna subcontractors are responsible for the following equipment:

Beacon antenna equipment (Radcom)
Recovery antenna equipment (Airborne Instrument Laboratories)
2-KMC high-gain antenna equipment (Avien)

9.2.2.3 Other Spacecraft Equipment Subcontractors

9.2.2.3.1 Television Equipment Test Program (RCA). RCA will conduct an extensive test program during the television equipment design and development. Included in the test program will be development and design verification tests.

9.2.2.3.1.1 Development Tests. Development tests will be conducted by RCA on breadboard circuits and one breadboard unit of the television equipment. The tests will be performed early in the design period, and will consist of unit and circuit functional tests and component evaluations. Information obtained from these tests will be used in the E-model design.

9.2.2.3.1.2 Design Verification Tests. RCA will conduct design verification tests on three E-models of the television equipment. These tests are designed to provide information that will enable RCA to design D-models that will have a high probability of passing the qualification tests. Table 9-1 shows the design verification tests to be conducted, and the utilization of the three E-models.

9.2.2.3.2 Central Timing Equipment (CTE) Test Program (Elgin). Elgin will conduct an extensive test program during the design and development of the CTE. The program will consist of development and design verification tests to assure compliance with the equipment specification (MC456-0006).

9.2.2.3.2.1 Development Tests. Development tests will be conducted early in the design phase on the CTE circuits and the complete breadboard unit. The tests will consist of functional electrical tests on circuits and the unit, along with performance tests under selected environmental conditions. Included in the environmental tests will be high-temperature tests on the CTE breadboard, and an evaluation of the stability of the temperature-compensated oscillator under temperature variations. In addition, circuits and components will be tested for interference susceptibility. Modifications resulting from information obtained during the initial portion of development tests will be incorporated in the E-model. Information obtained subsequent to the E-model design freeze will be used to aid in the D-model design phase. The development tests will be conducted at the Eglin facility.

9.2.2.3.2.2 Design Verification Tests. Design verification tests will be conducted on one E-model CTE. The tests will be conducted to gain test information that will enable Eglin to update the E-model design to a configuration that has a high probability of passing qualification tests. The tests will be designed to locate significant failure modes; determine the effects of critical single and combined environments, of functional stresses, of combinations of tolerances; and to determine design margins. The combined environments portion of the design verification tests will be conducted by a testing laboratory in the immediate vicinity of Eglin.

Table 9-1. Design Verification Test Program (RCA)

Test Conditions	Sequence of Tests		
	Assembly Number 1	Assembly Number 2	Assembly Number 3
Examination of product	1	1	1
Dielectric strength	2	2	2
Insulation resistance	3	3	3
Redundant circuit	4	4	4
Functional	5	5	5
Leakage	6		6
Humidity		6	
Acoustics		7	7
Vibration	7		8
Acceleration	8		
Electromagnetic interference	9	8	
Explosive atmosphere			9
Oxygen atmosphere	10		
Shock	11		

9.2.2.3.3 Up-Data Link Equipment Test Program (Motorola). Motorola will conduct an extensive test program during the design and development of the up-data link equipment. The program will include development and design verification tests.

9.2.2.3.3.1 Development Tests. Development tests will be conducted by Motorola on breadboard circuits to establish the electronic design. The results of these tests will be used to make any necessary changes in the E-models before their assembly. D-model design will be established on the basis of the development tests.

9.2.2.3.3.2 Design Verification Tests. Design verification tests will be conducted on three E-models of the up-data link equipment. The tests will be conducted to provide test information enabling Motorola to modify the D-model design to a configuration with a high probability of passing qualification tests.

9.2.3 Equipment

The subcontractors will use the following equipment which may be provided by the subcontractor or by a testing laboratory whose services are procured by the subcontractor:

Climate chambers
Humidity chambers
Vibration machines
Shock testers
Acoustic chambers
Vacuum chambers
Explosion chambers
Centrifuges
RFI shield rooms
Antenna pattern ranges
Laboratory test equipment and recorders

The major subcontractor also will provide a command module mock-up for use in the system-type tests.

9.2.4 Facilities

Unit test equipment (UTE) will be provided and used by the subcontractors in the testing of the equipment. The major subcontractor also will provide modified bench maintenance equipment for use in its system-type tests.

9.2.5 Test Schedule

The subcontractor test schedules are shown in Figures 9-2, 9-3, and 9-4.

9.3 S&ID TEST PLAN

9.3.1 Objectives

The objectives of the S&ID tests, on equipment other than antennas, are: to verify that performance of E-model equipment received for engineering tests are within specified limits; to explore any interface problems that may occur after installation of this equipment in a complete communications system breadboard; to isolate and determine the cause of malfunctioning equipment; and to verify the acceptable condition of spare equipment.

The objectives of the S&ID tests of antennas are to calibrate and align the 2-KMC high-gain antenna prior to installation on the S/M, and to develop the S&ID fabricated VHF/2-KMC scin antennas.

The objectives of the spacecraft—GOSS compatibility tests are:

1. To determine the compatibility of the spacecraft communications system with the GOSS interfaces;

2. To verify the spacecraft communications system performance with GOSS under the constraints of the mission;

3. To investigate engineering changes designed to eliminate incompatibilities between spacecraft, communications system and GOSS;

4. To test engineering concepts for optimizing the over-all communications link; and

5. To evaluate the modified GOSS-spacecraft communications system performance to ensure the removal of incompatibilities.

9.3.2 Test Plan

9.3.2.1 Equipment Tests on Bench Maintenance Equipment (BME)

Tests will be performed as necessary using the BME for performance, verification, and maintenance. Tests made on the BME will enable isolation to the module or lowest plug-in unit level. After the replacement with a spare module, a modified electrical portion of the equipment acceptance

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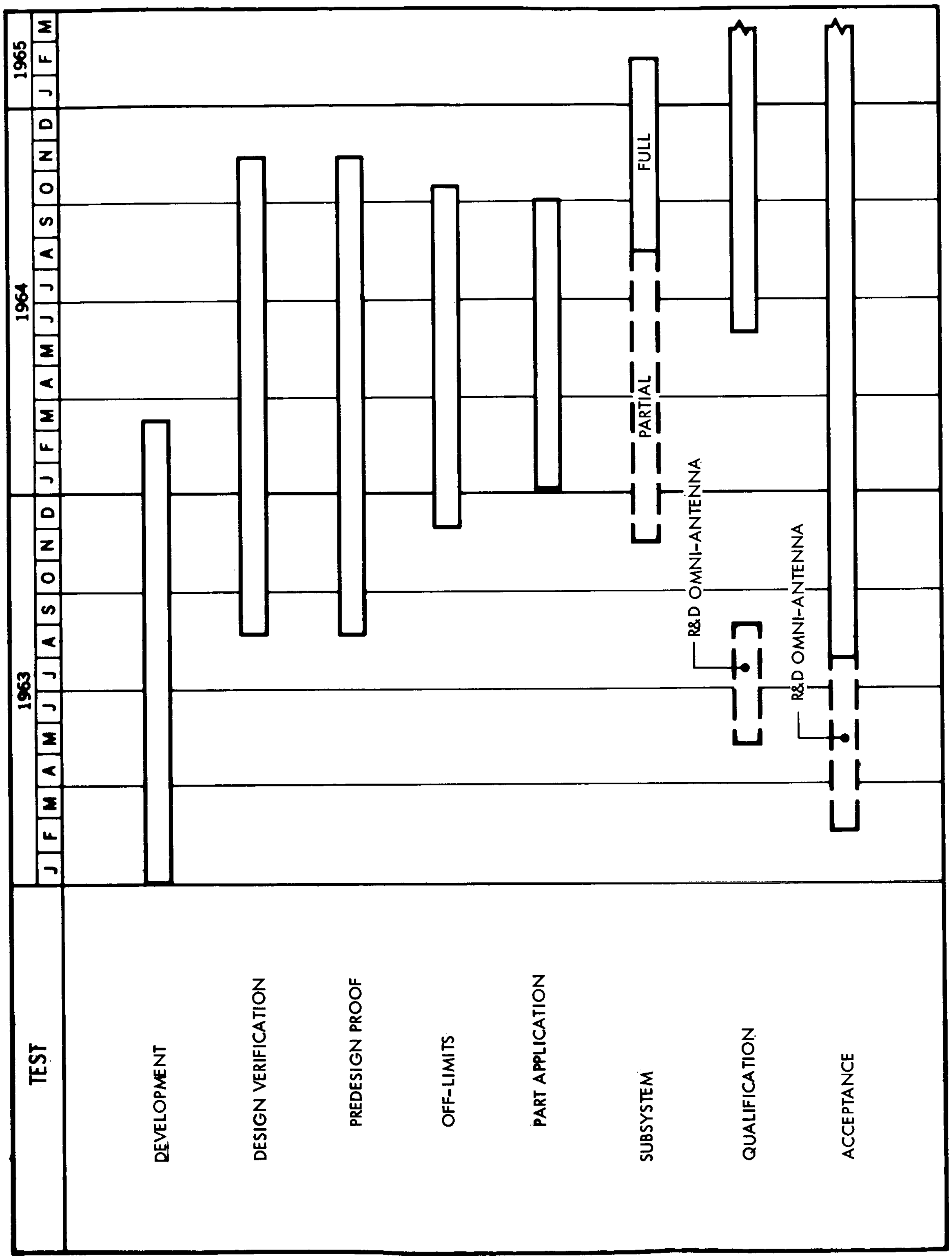

Figure 9-2. Major Subcontractor Spacecraft Equipment Tests

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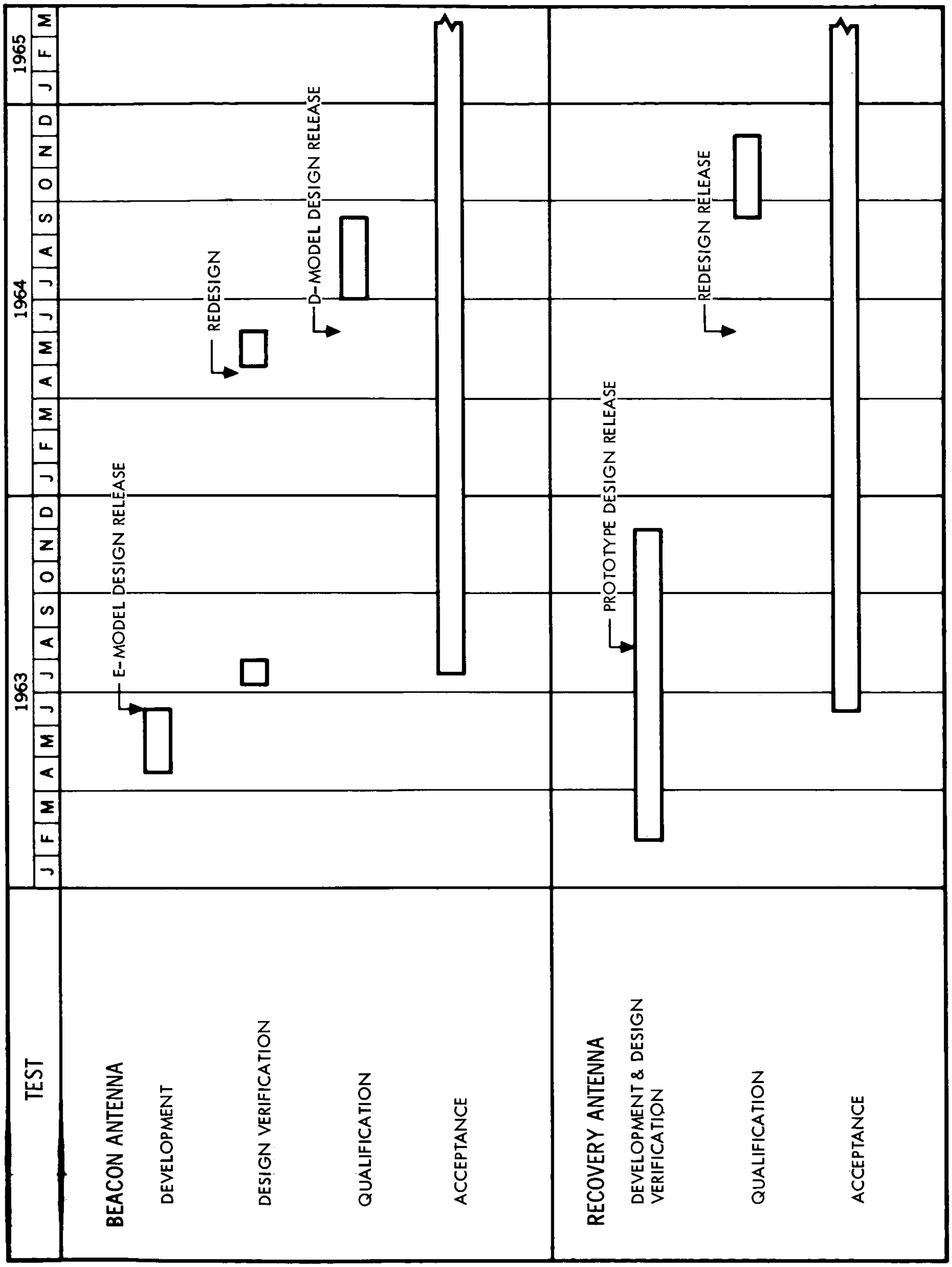

Figure 9-3. Operational Antenna Subcontractor Equipment Tests

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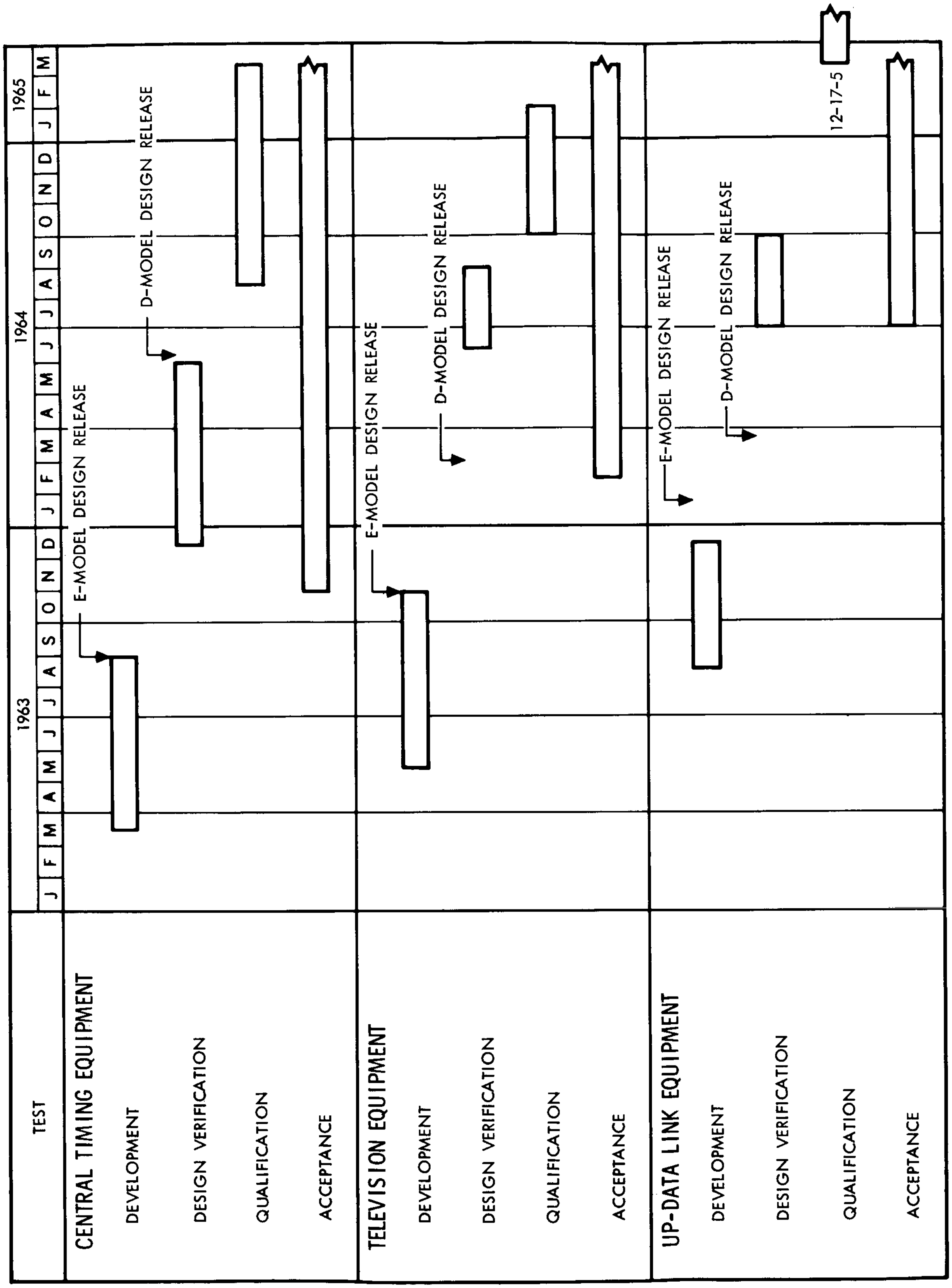

Figure 9-4. Other Spacecraft Equipment Subcontractor Tests

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[redacted]

test will be performed on the BME to return the package to the status of an acceptable spare. This modified electrical portion of equipment acceptance tests will be performed on spare equipment, at specified intervals, to verify their status as acceptable spares.

9.3.2.2 Engineering Tests on E-Model System

Two or more E-models of all equipment except antennas and central timing equipment will be delivered to NAA after completion of the in-house design verification tests by the subcontractors. One set of this equipment will be used by NAA in the spacecraft—GOSS compatibility test program, and the other set will be installed in a communications system breadboard in the laboratory. This will afford the first opportunity to integrate the complete system, other than the tests of the system which will be started in B-14, at approximately the same time. The test programs for the engineering breadboard system and for the system in B-14 will complement each other and form an effective support to the operational spacecraft systems. The engineering breadboard system cannot accurately simulate the interference and interface problems resulting from the spacecraft wiring and other systems. This can only be achieved adequately in the in-house spacecraft program. However, system tests can be performed on the engineering breadboard system to investigate internal system interface problems not caused by spacecraft installation effects. These tests that will be performed in the laboratory will reduce the requirement for scheduling test time on the spacecraft that normally would interfere with other spacecraft system tests. Freed from the confined area of the lower equipment bay in the spacecraft, the investigation of the problem and the determination of an optimum solution can be accelerated. Verification of the solution will be accomplished in the spacecraft. Use of the engineering breadboard system will permit the use of a greater variety of test equipment in the solution of problems than would be possible with the equipment installed in the spacecraft. The engineering breadboard system will be used: to explore the variation of equipment parameters under unique operating conditions; as a training aid; to obtain information when preparing or correcting process specifications; and as an engineering tool to evaluate the system effects of new equipment and techniques.

A test program to verify that the performance of the E-model equipment will be within specified limits and to explore any interface problems within the communications system is illustrated by the equipment and system tests that follow.

9.3.2.2.1 <u>VHF-FM Transmitter</u>

9.3.2.2.1.1 Equipment Test. Proper operation of the VHF-FM transmitter will be verified by the following tests.

[redacted]

1. Power Supply Voltages. Power supply voltages will be measured at the test points provided.

2. Output Power. The transmitter output will be terminated in a load simulating that of the spacecraft through a dual directional coupler with coupling arms that will be used to measure the incident and reflected power. The unmodulated power output will be not less than 10 watts.

3. Output Frequency. The coupled output from the forward terminal of the dual directional coupler will be terminated in a frequency counter to measure the output frequency with no modulation applied.

4. Frequency Deviation. The transmitter output from the forward terminal of the dual directional coupler will be terminated in the input connector of a transfer oscillator, which will be used in conjunction with a frequency counter and oscilloscope to measure frequency deviation by the bow-tie method. With the transmitter modulated by a sine wave of proper amplitude at a number of frequencies between 20 cps and 50 kc, the frequency deviation will measure ±125 kc within a ±10-kc tolerance.

5. Frequency Deviation Linearity. With the same test setup as in test 4, the transmitter will be modulated by a 16-kc sine wave in increments of 0.5 volts peak-to-peak, and will result in a voltage versus frequency plot linear within ±2.5 percent over the peak-to-peak deviation of 250 kc.

6. AFC Voltage. The AFC voltage will be measured at the test point provided.

9.3.2.2.1.2 System Test. Proper operation of the VHF-FM transmitter in conjunction with the other equipment in the communications system will be verified by tests 1, 2, 4, and 6 of paragraph 9.3.2.2.1.1.

9.3.2.2.2 VHF-AM Transmitter - Receiver

9.3.2.2.2.1 Equipment Test. Proper operation of the VHF-AM transmitter-receiver will be verified by the following tests.

1. Receiver Sensitivity. A VHF signal of 70-percent amplitude modulated by 1000 cps corresponding to each of the receiver frequencies will be applied to the receiver input. The signal level that is required to produce a 10-db signal plus noise-to-noise ratio at the receiver audio output will be measured.

2. Receiver Distortion. The over-all receiver distortion will be measured at the receiver audio output with a distortion analyzer when a VHF-AM signal is applied to the receiver input.

3. Receiver Frequency Response. The frequency response as measured with a meter having a 600-ohm impedance will be flat within ±3 db from 300 to 2300 cps when referenced to 1000 cps.

4. Power Supply Voltage. The power supply voltage will be measured at the test points provided.

5. Transmitter Output Power. The transmitter output power level will be measured with the transmitter terminated in a load with a VSWR of 2:1 through a directional coupler with a coupling arm that will be used to measure the incident power while operating with no modulation.

6. Transmitter Output Frequency. While operating in the same mode as in test 5, the output frequency will be measured by connecting the coupling arm to a frequency counter.

7. Transmitter Modulation. The percent of amplitude modulation of the transmitter carrier will be measured while a 1000-cps tone is applied to the transmitter audio input.

8. Transmitter Distortion. The distortion of the transmitter carrier and its modulation envelope will be measured while a 1000-cps modulation voltage is supplied to the transmitter at an amplitude just below the clipping level of the transmitter, with its output properly connected to a calibrated receiver and distortion analyzer.

9.3.2.2.2.2 System Test. Proper operation of the VHF-AM transmitter-receiver in conjunction with the other equipment in the communications system will be verified by the following tests.

1. Tests 4, 5, and 6 of paragraph 9.3.2.2.2.1 will be used.

2. The intelligibility of voice transmission and reception will be verified. A method of measuring intelligibility will be determined.

9.3.2.2.3 Unified S-Band Equipment.

9.3.2.2.3.1 Equipment Test. Proper operation of the unified S-band equipment will be verified by the following tests.

[redacted]

1. Power Supply Operation. The power supply voltages will be measured at the access points.

2. Primary Power. The primary power will be measured. The maximum power for any equipment operating mode will be 14 watts.

3. Transmitter Frequency Auxiliary Oscillator Mode. The output frequency will be measured with no modulation into the transmitter.

4. Transmitter Frequency, VCO Mode. The output frequency will be measured while applying an input signal, with its amplitude set at a value which gives a specified AGC voltage to the receiver. The input signal will be varied over the specified frequency range in 10-kc steps. The output frequency will be 240/221 times the input frequency.

5. Nominal Assigned Frequencies, VCO Mode. The input frequency will be measured with an input signal set to give a specified output frequency, as in test 4 above. The ratio of output to input frequencies will be 240/221.

6. Output Power, Auxiliary Oscillator Mode. The transmitter output power level will be measured with no modulation applied. The power level will be 250 to 400 mw in either PM or FM modes.

7. Output Power, VCO Mode. The transmitter output power level will be measured with no modulation while applying an input signal to the receiver with its amplitude set as in test 4 above, but being swept in frequency over the specified range. The power level will remain between 250 and 400 mw in either PM or FM modes.

8. Receiver Threshold. For an input signal with frequency of that measured in test 5 above, the threshold will be measured as the amplitude of input signal required to set the AGC voltage to the specified value.

9. Receiver Threshold Variation. From test 8 above, the input signal frequency will be varied ±60 kc, and verification will be made that the input amplitude need not be varied more than 0.5 db to maintain the AGC level, as given in test 8 above.

10. Receiver Dynamic Range. From test 8 above, verification will be made that the input signal amplitude can be increased 80 db without limiting of the AGC voltage.

[redacted]

11. Modulation Phase Detector. The up-voice output will be measured while a test signal, phase modulated by a 30-kc signal, is applied to the receiver input. The output will be 1.00±0.05 volts per radian of carrier deviation by the 30-kc signal.

12. Ranging Operation. The transmitted output signal will be detected with the equipment in the ranging mode and while a signal, as determined in test 5 above, which has been phase modulated by a 500-kc square wave to a 1-radian deviation, is applied to the receiver input. The detected signal will be examined for the proper characteristics.

13. Output Spectrums. The transmitter output spectrum will be recorded when the modulators have applied a set of specified tones to their inputs, one at a time. The auxiliary oscillator mode will be used.

9.3.2.2.3.2 System Test. Proper operation of the unified S-band equipment, in conjunction with the other equipment in the communications system, will be verified by the following tests.

1. Tests 6, 7, 8, 9, 12, and 13 of paragraph 9.3.2.2.3.1 will be used.

2. The signal from this equipment will be checked for degradation by other equipment.

9.3.2.2.4 S-Band Power Amplifier Equipment

9.3.2.2.4.1 Equipment Test. Proper operation of the S-band power-amplifier equipment will be verified by the following tests.

1. Power Output, Equipment Off. A 250-mw input signal at the assigned frequency will be applied at the input, and an output signal of 165-mw minimum will be verified.

2. Power Output, Low Gain. With an input signal identical to that in test 1 above, and two minutes or more after equipment turn-on, an output signal of 3.3 (+0.6, -0.4) watts will be verified.

3. Power Input, Low Gain. When operated in test 2 above, a primary power input not exceeding 35 watts will be verified.

4. Power Output, High Gain. With an input signal identical to that in test 1 above, and two minutes or more after equipment turn-on, an output signal of 14.5 watts or more will be verified.

[redacted]

5. Power Input, High Gain. When operated in test 4 above, a primary power input not exceeding 80 watts will be verified.

6. Switching Functions. The following operations will be verified. When the equipment is switched on, the output signal power will remain at the level given in test 1 above for the specified time delay. The output signal will be one of those given in test 2 or test 4 above, with the primary input power being not more than 10 watts until the end of the delay time when it will increase to one of the levels given in test 3 or 5 above. The primary input power and output signal will change levels according to test 3 or 5, and test 2 or 4 above by proper command.

7. Signal Isolation. The signal level to the unified S-band equipment receiver from the diplexer during tests 1, 2, and 4 above will be verified to be attenuated a minimum of 60 db relative to the S-band power amplifier output. The signal level to the unified S-band equipment receiver from the diplexer will be verified to be not less than -1 dbm when a 0-dbm signal at a frequency 221/240 of that given in test 1 above is applied to the antenna connection.

9.3.2.2.4.2 System Test. Proper operation of the S-band power amplifier equipment, in conjunction with the other equipment in the communications system, will be verified by the following test. The various modes of operation will be verified similarly to test 6 of paragraph 9.3.2.2.4.1, except that the power levels may not be measured.

9.3.2.2.5 C-Band Transponder

9.3.2.2.5.1 Equipment Test. Proper operation of the C-band transponder will be verified by the following tests.

1. Receiver Sensitivity. A test signal at the assigned frequency will be applied to each receiver channel in turn to determine the triggering sensitivity. The test signal will have a repetition rate of 500 pps. The sensitivity will be checked for a single-pulse interrogation and for a pre-set two-pulse coded interrogation.

2. Receiver Tuning. Each receiving channel will be checked to determine that it is tuned to the assigned frequency within ±1 mc.

3. Transmitter Output Power. The peak pulse power of the transmitter will be determined with the transponder being triggered at a 500-pps rate.

[redacted]

4. Transmitter Output Frequency. The output signal of test 3 will be connected to a wavemeter to determine that the output is at the assigned frequency, within ±4 mc.

5. Comparator Operation. Verification of proper operation of the comparator will be obtained by applying appropriate signals to alternate inputs of the transponder.

6. Random Noise Firing. With the receiver inputs terminated in dummy loads, the random noise firing of the transmitter will be checked with a counter to verify that it is within the acceptable limit.

7. Countdown. The transmitter reply rate will be monitored with a counter to determine that it does not exceed the pre-set rate when the receiver is intentionally over-interrogated.

9.3.2.2.5.2 System Test. Proper operation of the C-band transponder, in conjunction with the other equipment in the communications system, will be verified by the following tests.

1. Tests. Tests 1, 3, and 5 of paragraph 9.3.2.2.5.1 will be used.

2. Random Noise Firing. With the system installed in its flight-ready configuration and set for single-pulse interrogation, the transmitter will be monitored with a counter to verify that communications equipment signals do not cause excessive noise firing.

9.3.2.2.6 VHF Recovery Beacon

9.3.2.2.6.1 Equipment Test. Proper operation of the VHF recovery beacon will be verified by the following:

1. Power Supply Voltages. The power supply voltages will be measured at the test points provided.

2. Output Power. The VHF recovery beacon will be terminated in a load with a VSWR of 2:1 through a directional coupler with a coupling arm that will be used to measure the incident power.

3. Output Frequency. The output of the coupler arm will be fed into a counter for a direct measurement of frequency.

4. VHF/BCN Auto Mode. The proper operation of the VHF/BCN auto mode will be verified.

[redacted]

9.3.2.2.6.2 System Test. Proper operation of the VHF recovery beacon, in conjunction with the other equipment in the communications system, will be verified by tests 1 and 2 of paragraph 9.3.2.2.6.1.

9.3.2.2.7 <u>HF Transceiver</u>

9.3.2.2.7.1 Equipment Test. Proper operation of the HF transceiver will be verified by the following tests.

1. <u>Receiver Sensitivity (AM and SSB)</u>. The receiver sensitivity will be measured by means of the minimum discernible signal (MDS) technique. A calibrated signal generator and an HF spectrum analyzer should be used. In the SSB position, the transmitter will be modulated with a 1000-cps tone.

2. <u>Receiver AGC Voltage (AM and SSB)</u>. The receiver AGC voltage will be measured with a high input impedance VTVM. The RF input voltage will be varied from 10 to 100,000 microvolts, and AGC voltage will be monitored to ascertain that it remains within specified limits.

3. <u>Transmitter Carrier Output Power (AM)</u>. The transmitter carrier output power will be determined without modulation being applied and with the transmitter tuned to optimum performance. An in-line directional coupler will be connected in the circuit so that its coupling arm can be used to monitor the incident power. The transmitter will be terminated into a nominal 50-ohm resistive load.

4. <u>Transmitter Output Frequency (AM)</u>. The transmitter output frequency will be measured by connecting a high-frequency counter to the coupling arm of the directional coupler.

5. <u>Hum and Noise Output (AM)</u>. The hum and noise output of the transmitter will be monitored on an oscilloscope with the equipment operating at rated power output.

6. <u>Voltage Standing Wave Ratio (AM)</u>. The output of the transmitter will be connected to an in-line directional coupler. VSWR will be read on a standing wave ratio bridge, or equivalent. The transmitter will be operated at rated power and terminated into a nominal 50-ohm resistive load.

7. <u>Transmitter Power Output (SSB)</u>. The transmitter output power will be measured by applying a two-tone audio signal to the

input and monitoring power output through a directional coupler on a suitable indicating device. The transmitter will be terminated with a nominal 50-ohm resistive load.

8. Transmitter Spurious Output (SSB). The transmitter output intermodulation distortion products and unwanted sidebands will be measured using spectrum analysis techniques. The output of the transmitter will be connected to an in-line directional coupler and terminated into a nominal 50-ohm resistive load.

9. Transmitter Carrier Suppression (SSB). The suppression of the RF carrier will be measured with a spectrum analyzer to verify that the carrier remains within the specified limits. The output of the transmitter will be displayed on the spectrum analyzer, and the level of sideband will be compared to the level of suppressed carrier to establish the degree of suppression.

10. Transmitter Noise Level (SSB). The output of the transmitter will be connected to an oscilloscope through a directional coupler. The transmitter will be connected to a nominal 50-ohm resistive load. With the transmitter operating at rated output, noise on the carrier will appear as a ripple on the oscilloscope display.

9.3.2.2.7.2 System Test. Proper operation of the HF transceiver, in conjunction with the other equipment in the communications system, will be verified by measuring the intelligibility of voice transmission and reception will be verified in the SSB and AM modes. A method of measuring intelligibility will be determined.

9.3.2.2.8 Audio Center Equipment

9.3.2.2.8.1 Equipment Test. Proper operation of the audio center equipment will be verified by the following tests.

1. AVC Threshold Level of Microphone and Earphone Channels. Using a 1000-cps signal, the AVC threshold input signal level will be verified to be between -16 and -10 dbm for each of the microphone channels, and between 1.27 and 2.53 volts for each of the earphone channels. The signal source impedance will be 600 ohms.

2. Channel Gain of Microphone and Earphone Amplifier Channels. Using a 1000-cps tone with the input levels set at AVC threshold, outputs of 0 dbm across 600 ohms for each of the microphone amplifier channels, and 20 dbm across 600 ohms for each of the earphone amplifier channels, will be verified. In each amplifier, an input signal increase of 20 db will cause the output to increase no more than 4 db.

[redacted] [redacted]

3. Frequency Response of Microphone and Earphone Amplifier Channels. The frequency response of each of the microphone and earphone amplifier channels will be measured at a level just below the AVC threshold to verify that the response is constant, within +1 and -3 db, relative to 1000 cps over the range of 300 to 3000 cps. Source and load impedances will be 600 ohms.

4. AVC Attack Time of Microphone and Earphone Channels. The AVC attack time of each of the microphone and earphone channels will be measured by observing the output while a 1000-cps signal at the input is stepped from the AVC threshold value to a value 10 db above threshold.

5. AVC Release Time of Microphone and Earphone Channels. The AVC release time of each of the microphone and earphone channels will be measured by observing the output while a 1000-cps signal at the input is stepped from a value 10 db above AVC threshold to the threshold value.

6. Distortion. The distortion of each of the microphone and earphone amplifier channels will be measured using an input signal level 20 db above the AVC threshold. Source and load impedances will be 600 ohms.

7. Internal Noise. The internal noise level of all audio channels will be measured at each of the three modulation outputs and at the earphone output of each audio center module.

8. VOX Sensitivity. The sensitivity of the VOX circuitry in each audio center module will be measured by applying a 1000-cps tone to each microphone input and monitoring the side tone in the earphone output of the same module. The VOX sensitivity control will be capable of controlling the output signal with a variation of the input signal from +10 to -10 dbm.

9. VOX Attack and Release Times. The attack time and release time of the VOX circuitry in each audio center module will be measured by applying a 1000-cps signal to each microphone input and monitoring the dc voltage at one of the two transmitter keying circuits.

10. Isolation. Isolation between receiver inputs will be measured by applying a 1000-cps tone at a level of 0.8 volts rms at one of the three receiver inputs and measuring the signal at each of the other

two receiver inputs. All three inputs will be terminated with source impedance of 600 ohms. With any combination of switching of the receiver inputs, the isolation will be at least 50 db. Isolation between modulation outputs will be measured by applying 1000-cps tone to one of the three modulation outputs and measuring the signal at each of the other two modulation outputs. The tone at the modulation output can be obtained by applying a 0-dbm signal to the microphone input of one of the audio center modules. All three modulation outputs will be terminated with load impedances of 600 ohms. With any combination of switching of the modulation outputs, the isolation will be at least 30 db.

9.3.2.2.8.2 System Test. Proper operation of the audio center equipment in conjunction with the other equipment in the communications system will be verified by the following tests.

1. Intercom Operation. A voice input will be applied to the microphone at each astronaut position and monitored on the earphone outputs at the other two positions for verification of intelligibility, VOX and PTT operation, volume control adjustments, balance control adjustments, and side-tone attenuation.

2. Communications and Data Storage Operation. The intelligibility of voice recording and playback on the data storage equipment and the transmission and reception over the RF links will be verified. VOX and PTT operation will be verified. A method of measuring intelligibility will be determined.

9.3.2.2.9 Premodulation Processor Equipment

9.3.2.2.9.1 Equipment Test. Verification of the proper operation of the premodulation processor equipment will be made so that, with no adjustments, the premodulation processor will produce the outputs for the various modes shown in Table 9-2, with the inputs shown in Table 9-3.

9.3.2.2.9.2 System Test. Proper operation of the premodulation processor equipment in conjunction with the other equipment in the communications system will be verified by the following procedure. Signals from the related equipment will be used as inputs to the premodulation processor, and outputs will be sent to the related equipment as shown in Tables 9-2 and 9-3.

9.3.2.2.10 PCM Telemetry Equipment

9.3.2.2.10.1 Equipment Test. Proper operation of the PCM telemetry equipment will be verified by the following tests.

[redacted]

Table 9-2. Premodulation Processor Outputs

Switch	Switch Position and Mode	Output to	Output
4	Emergency voice	USBE (FM-2)	3 kc analog voice, 0.26 v peak
	Normal voice	USBE (PM)	1.25 mc VCO, 0.84±0.04 v peak (voice)
		USBE (PM)	Biphase 1.024 mc PCM, 1.1±0.05 v peak
	Emergency key	USBE (PM)	512 kc sine wave, 1.1±0.05 v peak
5	Ranging A	USBE (PM)	1.25 mc VCO, 0.84±0.04 v peak (voice)
	Off		
	Ranging B	USBE (PM)	1.25 mc VCO, 0.84±0.04 v peak (voice)
		USBE (PM)	Biphase 1.024 mc PCM, 1.1±0.05 v peak
6	Tape**	USBE (FM-1)	1.25 mc VCO, 0.266±0.01 v peak (voice, RT)
		USBE (FM-1)	Biphase 1.024 mc PCM, 0.233±0.015 v peak (S)
		USBE (FM-1)	9 FM channels, 0.0675±0.005 v peak (S)
	Off		
	Analog	USBE (FM-1)	1.25 mc VCO, 0.266±0.01 v peak (voice, RT)
		USBE (FM-1)	Biphase 1.024 mc PCM, 0.233±0.015 v peak (RT)
		USBE (FM-1)	9 FM channels, 0.0675±0.005 v peak (RT)
7	TV	USBE (FM-1)	0 to 500 kc TV, 1±0.05 v peak
		USBE (FM-1)	1.25 mc VCO, 0.266±0.01 v peak (voice)
		USBE (FM-1)	Biphase 1.024 mc PCM, 0.233±0.015 v peak
	Off		
	Relay	USBE (FM-1)	0 to 13 kc biomed data, 0.203±0.01 v peak
		USBE (FM-1)	1.25 mc VCO, 0.266±0.01 v peak (voice)
		USBE (FM-1)	Biphase 1.024 mc PCM, 0.233±0.015 v peak
12	PCM	VHF-FM transmitter	Filtered PCM, 1.5±0.15 v peak
	Off		
	Relay	VHF-FM transmitter	Filtered PCM, 1.0±0.1 v peak
		VHF-FM transmitter	0 to 13 kc biomed data, 0.6±0.066 v peak
16	Record***	DSE	PCM data, same as input
		DSE	9 analog channels, same as input
	Off		
	Play (Provides power to DSE playback electronics)		
19	PCM (PCM playback only)	USBE (FM-1)	9 FM channels, 0.0675±0.005 v peak (RT)
		VHF-FM transmitter	Filtered PCM, 1.5±0.15 v peak (S)
		USBE (FM-1)	Biphase 1.024 mc PCM, 0.233±0.015 v peak (S)
		USBE (FM-1)	1.25 mc VCO, 0.266±0.01 v peak (voice, RT)
	Normal**, analog + PCM playback	VHF-FM transmitter	Filtered PCM, 1.5±0.15 v peak (S)
		USBE (FM-1)	Biphase 1.024 mc PCM, 0.233±0.015 v peak (S)
		USBE (FM-1)	9 FM channels, 0.0675±0.005 v peak (S)
		USBE (FM-1)	1.25 mc VCO, 0.266±0.01 v peak (voice, RT)
	Analog**, analog playback only	USBE (FM-1)	9 FM channels, 0.0675±0.005 v peak (S)
		UHF-FM transmitter	Filtered PCM, 1.5±0.15 v peak (RT)
		USBE (FM-1)	Biphase 1.024 mc PCM, 0.233±0.015 v peak (RT)
		USBE (FM-1)	1.25 mc VCO, 0.266±0.01 v peak (voice, RT)

*All of the above mode switches are the three-position toggle type.

PCM data may be at high or low bit rates (51.2 or 1.6 KB/S).

Up-voice and up-data outputs to the audio center and up-data decoder may be provided during all of the above modes of operation.

Abbreviations

- DSE - data storage equipment
- PCM - pulse coded modulation
- PMP - premodulation processor
- USBE - unified S-band equipment
- VCO - voltage controlled oscillator
- S - stored data from the DSE
- RT - real time

**Voice playback is provided on one of the nine FM channels by the DSE.

***Selects the record mode of the PMP. Any one of the other modes may be used at the same time.

[redacted]

Table 9-3. Inputs to Premodulation Processor

Input From	Voltage Level	Frequency
PCM equipment	6±0.5 v = 1; 0(+0.5, -0) = 0 0 to 6v	51.2 KB/S or 1.6 KB/S 512 kc (square wave)
Central timing equipment	0 to 3v	512 kc (square wave)
Key	0 v	dc
Audio center	1.38(+0.9, -0.65) v peak	0 to 3 kc
TV equipment	2.0±0.1 v peak to peak	0 to 500 kc
Dist. panel	0 to 5 v (18 inputs)	5 kc maximum
Biomed from VHF-AM receiver	2.27±0.25 v peak	13 kc maximum
USBE	0.2 to 5.0 v peak 0.2 to 5.0 v peak	30±7.5 kc (up-voice) 70±5 kc (up-data)
DSE	6±0.5 v = 1;0(+0.5, -0) = 0 0 to 5 v (9 inputs)	51.2 KB/S (recorded) 5 kc maximum (recorded)

[redacted]

1. Verification will be made that all inputs required for proper operation are as specified. These inputs will include (excluding S/C measurement signals) (1) timing signals from the spacecraft central timing equipment—512-kc and 1-cps square waves (measure frequency, amplitude, wave shape, and phase relationship) and (2) power—115 volts, 400 cps, 3 phase (measure frequency, voltage, phase, load balance, and total power).

2. A go status for all PCM telemetry condition (go, no-go) signals will be verified.

3. Verification will be made that analog operating voltages are within the specified tolerances. These will include all calibrate voltages and all digital logic supply voltages.

4. A selected number of internal digital programming signals will be verified for proper sequencing, waveform, and frequency.

5. All digital output timing signals will be verified for specification compliance.

6. PCM data output pulse trains will be verified for the occurrence of special digital words with appropriate decommutation equipment. Some gating pulses will be available at the access connector to simplify the required test equipment.

7. Measurement input signals will be simulated at the data distribution panel, and the PCM equipment data outputs will be correlated with the known inputs. This will be a gross check to identify faulty channels.

8. Measurement input signals will be controlled as in test 7, except that the data outputs will be recorded digitally. The resultant tapes will be analyzed at the data acquisition and recording station to determine the performance of individual PCM channels.

9. As a supplementary test to test 8, the PCM data output pulse trains will be evaluated for bit error rate and its effects with various amounts of injected noise.

9.3.2.2.10.2 System Test. Proper operation of the PCM telemetry equipment in conjunction with the other equipment in the communications system will be verified by tests 1, 2, 3, and 5 of paragraph 9.3.2.2.10.1.

[redacted]

9.3.2.2.11 Signal Conditioning Equipment

9.3.2.2.11.1 Equipment Test. Proper operation of the signal conditioning equipment will be verified by the following tests.

1. Verification will be made that, with proper adjustments, the dc amplifiers will produce an output of 0 to 5 volts dc with inputs of 0 to 20 mv dc and all intermediate ranges through 0 to 250 mv dc for types 01, 03, 04, 05, and 06; 0 to 250 mv dc and all intermediate ranges through 0 to 7 volts dc for type 02. Types 03, 04, 05, and 06 are dc amplifiers with the inactive bridge elements incorporated within. Verification will be made that, with proper adjustments, the differential bridge amplifier will produce an output of 0 to 5 volts dc directly proportional to inputs from strain gages and temperature sensors whose resistance varies from 100 ohms to 23.5 kilohms nominal.

2. Verification will be made that, with proper adjustments, the attenuators will produce an output of 0 to 5 volts dc with inputs of 0 to 7 volts dc and all intermediate ranges through 0 to 50 volts dc for type 40; 0 to -7 volts dc and all intermediate ranges through 0 to -50 volts dc for type 41; 28±4 volts dc expanded scale for type 42.

3. Verification will be made that, with proper adjustments, the biphase demodulators will produce an output of 0 for an input signal of 0.5 volts rms and all intermediate ranges through 5 volts rms 180 degrees out of phase with the reference signal, an output of 2.5 volts dc for a 0 input signal, and an output of 5 volts dc for an input signal of 0.5 volts rms and all intermediate ranges through 5 volts rms in phase with the reference signal for type 30. The type 31 will perform in the same manner, except that the signal input values will be 5 volts rms and all intermediate ranges through 50 volts rms. The reference signal will be the same frequency as the input signal with amplitudes of 26, 50, or 115 volts rms ±2 percent.

4. Verification will be made that, with proper adjustments, the frequency converters will produce an output of 0 to 5 volts dc directly proportional to the input frequency, 0 volts dc output at 380 cps, and 5 volts dc output at 420 cps in the range of 105 volts rms to 150 volts rms.

5. Verification will be made that, with proper adjustments, the ac to dc converters will produce an output of 0 to 5 volts dc with

inputs of 0 to 5 volts and all intermediate ranges through 150 volts rms for type 10, and expanded scale 115 volts rms from 105 to 125 volts rms for type 11. The input frequency range will be from 400 cps to 3200 cps.

6. Verification will be made that, with proper adjustments, the low-gain dc amplifiers will produce an output of 0 to 5 volts dc with inputs of ±2.5 volts dc and all intermediate ranges to ±35 volts dc for type 20.

9.3.2.2.11.2 System Test. Proper operation of the signal conditioning equipment in conjunction with the other equipment in the communications system will be verified by the tests, as in paragraph 9.3.2.2.11.1, performed on one of each type conditioner.

9.3.2.2.12 Data Storage Equipment.

9.3.2.2.12.1 Equipment Test. Proper operation of the data storage equipment will be verified by the following tests.

1. Verification will be made that, with proper adjustments, the analog channels will record a 0- to 5-volt, peak-to-peak, 50-cps to 10-kc signal, and, upon playback, reproduce the recorded signal within the required tolerances.

2. Verification will be made that, with proper adjustments, the digital electronics will convert a 0- and 6-volt, serial NRZ, 51.2-kilobit PCM signal to four parallel signals and record them along with a clock signal. Upon playback, the digital electronics will reproduce the parallel signals and convert them to a serial PCM signal identical to that which was presented at the input, within the required tolerances.

9.3.2.2.12.2 System Test. Proper operation of the data storage equipment in conjunction with the other equipment in the communications system will be verified by tests 1 and 2 of paragraph 9.3.2.2.12.1.

9.3.2.2.13 Central Timing Equipment.

9.3.2.2.13.1 Equipment Test. Proper operation of the central timing equipment will be verified by the following tests.

1. Verification will be made that with the 1024-kc input present and with all outputs terminated in 100-ohm loads:

a. All outputs will have an amplitude of 3±0.3 volts on no greater than 50-mv dc offset.

b. The 512-kc outputs will have a 10- to 90-percent rise and fall time of no greater than 100 nanoseconds and all other frequency outputs will have a 10- to 90-percent rise and fall time of no greater than 500 nanoseconds.

c. All frequency outputs will have a duty cycle of 50±1.0 percent.

d. All frequency outputs will have an overshoot of no greater than 10 percent.

e. All frequency outputs will be at the correct frequency.

2. Verification will be made that without the 1024-kc input present and with all outputs terminated in 100-ohm resistive loads the requirements of test 1 will be satisfied.

9.3.2.2.13.2 System Test. Proper operation of the central timing equipment in conjunction with the other equipment in the communications system will be verified by tests, as in paragraph 9.3.2.2.13.1, that will be performed on all outputs of the central timing equipment that are utilized by communications equipment, and those pieces of equipment will be monitored to verify the compatibility of the central timing equipment with the rest of the communications system.

9.3.2.2.14 Television Equipment.

9.3.2.2.14.1 Equipment Test. Proper operation of the television equipment will be verified by the following test. The TV display of the reduced frame rate picture will be observed to verify:

1. A horizontal resolution of 250 lines and a vertical resolution of 225 lines

2. A gray-scale rendition of at least 5 gray scales

3. A sensitivity capable of providing the above resolution and gray-scale rendition with incident vidicon target highlight illumination as low as 0.1 foot-candle.

9.3.2.2.14.2 Systems Test. Proper operation of the television equipment in conjunction with the other equipment in the communications system will be verified by observing the resolution and gray-scale rendition as displayed.

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9.3.2.3 Antenna Test Program

9.3.2.3.1 VHF/2-KMC Scin Antennas. These antennas will be developed and fabricated at NAA. The development tests will be performed during the evolution of the final design. Antenna patterns will be obtained by using one-third-scale antennas and S/C models, and full-scale antennas. Impedance measurements will be made. Dielectric constant and loss tangent measurements will be made on ablator materials in both charred and uncharred conditions. Exploratory vibration tests will be performed. Tests in the vacuum chamber will be made to determine voltage breakdown characteristics.

9.3.2.3.2 2-KMC high-Gain Antenna Equipment. The following tests will be made on the 2-KMC high-gain antenna equipment at the antenna range before installation on the service module.

1. The electrical bore sight will be measured.

2. The IR sensor alignment will be measured and adjusted to coincide with the antenna RF axis.

3. The antenna servos will be calibrated.

4. Azimuth and elevation pattern cuts will be taken for each of the selectable beam widths.

9.3.2.4 Spacecraft—GOSS Compatibility Tests.

9.3.2.4.1 Spacecraft Communications System—GOSS Compatibility Tests. These tests will be necessary to evaluate mutual compatibility of spacecraft and ground communication systems under simulated operational conditions. The spacecraft-GOSS interface test system (SGITS) facility will be equipped with similar performing systems or duplicates of all GOSS interface systems necessary for this evaluation.

The compatibility tests will be conducted with the spacecraft equipment performing its specified function through an RF link tied to the SGITS facility (GOSS functional equipment). The RF link will alter the spacecraft signals so that they will appear to have originated from various positions in space. The signal carrier frequencies, stabilities, power modulation index, threshold and signal margins and intermodulation products will be measured and analyzed for the various communications modes and at signal levels corresponding with simulated space positions.

[redacted]

Communications subsystem tests will be performed to isolate design deficiencies of the various subsystems and to establish their performance capabilities. The primary objectives are to identify marginal performance of specific subsystems, to avoid degradation of performance due to interface mismatch, and to establish quantitatively the design performance capability of each subsystem when properly integrated into the over-all system.

9.3.2.4.2 Feasibility Tests of System and Techniques. These tests will verify the feasibility and performance of modifications to the over-all communications system, as well as individual units of the system under simulated constraints of the mission upon the RF link. The general philosophy will be to seek the simplest possible solution to the problems of incompatibility utilizing, where possible, corrections involving adjustments such as changes in levels or frequencies, rather than redesign of equipment. Results of these tests will be particularly valuable backup data for proposing improvements in the spacecraft-GOSS communications link.

When redesign of the system is required, breadboards of the modifications will be fabricated and tested to verify soundness of ideas, feasibility and optimization of techniques and equipment, conformity of system operation with system philosophy, and optimized formats of information codes. These tests will be performed primarily with the SGITS S/C console.

9.3.2.4.3 Evaluation Tests. Initial spacecraft-GOSS system evaluation tests to ensure optimum spacecraft-GOSS system performance will be conducted with breadboards of modifications that have been proved feasible for the Apollo mission. For further refinement, these tests will be accomplished in conjunction with the house spacecraft test program and will be evaluated for optimization in the actual spacecraft system configuration. Results of these evaluation tests then will be used to recommend that these modifications be incorporated or deleted from the spacecraft communications system.

9.3.3 Equipment

S&ID will provide or procure the use of the following equipment.

RFI shield room
Antenna pattern range
Laboratory test equipment and recorders
Engineering spacecraft simulator
Spacecraft mock-ups
Communications system breadboard

9.3.3.1 Equipment Required (GOSS Only)

The equipment needed to perform all of the feasibility, compatibility, and system evaluation tests will consist of a phase-lock receiver system; telemetry receivers; high- and low-data rate recorders; HF, VHF, and signal generators and receivers; C-band pulse generators; C-band signal generators; frequency standards, synthesizers; noise generators; pseudo-random noise generator and correlator; and, in general, all equipment that should go into a GOSS station, except the data processing systems, antenna systems, and computer.

This equipment will be connected together in the GOSS configurations for all of the tests.

The data ground station, located in Building 6, will support the tests by processing the data, where required.

9.3.4 Facilities

S&ID will provide and use the following facilities at Downey.

Bench maintenance equipment
Data acquisition and recording station
Spacecraft-GOSS interface test system (SGITS) facility

The SGITS facility will be located at S&ID in Downey. The facility will occupy a 30 by 30 foot area and will be composed of an operation area and a testing area.

9.3.5 Test Schedule

The S&ID communications system and the spacecraft-GOSS compatibility test schedules are shown in Figure 9-5.

9.4 INSTRUMENTATION SYSTEM TESTS

9.4.1 Objective

The objective of the instrumentation system tests will be to ensure that the system will furnish the required information in the specified form, from the source to the designated utilization points, under the specified environmental conditions without interfering with the designed function of other systems.

9.4.2 Test Plan

The test program consists of evaluation tests of representative transducers from potential sources to assist in final determination of the procurement source for each type of transducer, qualification tests, subsystem tests, and combined system tests. The items to be tested include sensors, associated equipment, subsystems, and special instrumentation such as optical, scientific, and biomedical.

9.4.2.1 Qualification Tests

9.4.2.1.1 Objective. The objective of qualification tests will be to ensure that the system components provided by the vendors will perform according to the specifications under defined environmental conditions and with sustained reliability over a delineated period of time.

9.4.2.1.2 Test Plan. The various system components will be tested for performance characteristics, such as linearity, hysteresis, stability, repeatability, and output level. During the tests, the components will be subjected to varying environmental conditions of vibration, shock, acceleration, acoustics, temperature, and radiation. Reliability will be determined by monitoring the component's output over an extended period of operation.

9.4.2.1.3 Program Requirements. Test articles will include such components as pressure transducers, temperature transducers, flow meters, quantitative transducers, acoustic transducers, vibration accelerometers, attitude gyros, rate gyros, signal conditioners, and ablation transducers. Data will be recorded by oscillographs, oscilloscope cameras, tape recorders, and other data-logging devices.

9.4.2.1.4 Equipment. Vacuum chambers, pressure chambers, ovens, etc., will be used to simulate the desired environmental conditions for test.

9.4.2.1.5 Facilities. The test facility will consist of a complete evaluation laboratory equipped with environmental chambers, measurement standards, recording equipment, and typical test equipment.

9.4.2.1.6 Test Schedules. Test schedules will vary for each component, dependent upon type, number of each type being tested, and the test vehicle for which it is intended.

9.4.2.2 Acceptance Tests

9.4.2.2.1 Objective. The objective of the acceptance tests will be to ensure that each component item received is in satisfactory operating condition and is capable of performance in accordance with the specifications.

9.4.2.2.2 Test Plan. Each component item received will be inspected initially to ensure good mechanical condition, correct dimensions, proper identification marking, etc. Following the receiving inspection, the individual component item will be subjected to an operational checkout that tests the performance characteristics of the item under limited environmental conditions indicated for the qualifying inspection. The preinstallation test will be performed immediately prior to delivery of the component item to manufacturing for system installation in a test vehicle. The preinstallation test essentially will be the same as the operational checkout. It will be performed to ensure that no degradation in performance has occurred during the shelf-time period of the component item.

9.4.2.2.3 Program Requirements. The program requirements will be the same as those for the qualification tests (paragraph 9.4.2.1.3).

9.4.2.2.4 Equipment. The equipment will be the same as that to be used for the qualification tests (paragraph 9.4.2.1.4).

9.4.2.2.5 Facilities. The test facility will consist of a complete evaluation laboratory equipped with environmental chambers, measurement standards, recording equipment, and typical test equipment. The test facility will be located at S&ID, Downey, California.

9.4.2.2.6 Test Schedule. Test start dates will occur toward the end of the manufacturing phase for each test vehicle involved.

9.4.2.3 Subsystem Tests

9.4.2.3.1 Objective. The objective of subsystem tests will be to determine the interaction of the components when they are functioning as part of the complete subsystem.

9.4.2.3.2 Test Program. Subsystem tests will be conducted in boilerplates or airframes, either during the manufacturing phase or after its completion. Input and output readings will be made at the appropriate check points to ensure that all instrumentation components in the system are functioning according to the design specifications. Malfunction, when occurring, will be investigated thoroughly. If the malfunction is caused by component interaction, the component that causes the malfunction may be redesigned.

9.4.2.3.2.1 Subsystem Tests. Subsystem tests to determine the compatibility of the components with other spacecraft subsystems, especially the electrical type, will be performed under operational conditions without simulated environment in B-14. The effects of an acoustical and vibration environment will be determined during subsystem tests conducted on Airframe 001, Test Fixture 2, and Airframe 006. The effects of the temperature and vacuum environments will be determined during subsystem tests conducted on Airframe 008.

9.4.2.3.2.2 Program Requirements. The test article will be the complete subsystem. Recording methods and recording equipment will be the same as the equipment to be used in the qualification tests (paragraph 9.4.2.1.3).

9.4.2.3.3 Equipment. Equipment to produce simulated environmental conditions will consist of a thermal vacuum space simulator for AFRM 008, an acoustic and vibration environment for AFRM 006, service propulsion and reaction control propulsion systems for AFRM 001, and a service propulsion system for Test Fixture 2.

9.4.2.3.4 Facilities. Test facilities for installation of the instrumentation subsystem will be the designated test vehicles. The test locations will be the Apollo Propulsion Systems Development facility WSMR for Airframe 001 and Test Fixture 2; the in-house Spacecraft 1 manufacturing area at NAA, S&ID, Downey, California, for Boilerplate 14, acoustic and vibration laboratory at NAA, S&ID, Downey, for Airframe 006; thermal vacuum space simulator at MSC, Houston, Texas, for Airframe 008; and the respective manufacturing and test sites for each vehicle for Airframe 009 and Airframe 011. Test facilities may be fixed (such as test stands), portable (such as individual items of test equipment), or mobile (such as instrumentation trailers).

9.4.2.3.5 Test Schedule. Test start dates will occur toward the end of the manufacturing phase for each test vehicle involved.

9.4.2.4 Integrated System Tests

9.4.2.4.1 Objective. The objective of combined system tests will be to determine the interaction of subsystems when they are functioning as a part of the complete system.

9.4.2.4.2 Test Program. Integrated system tests will be conducted in boilerplates or airframes upon completion of the manufacturing phase. Input and output readings will be made at the appropriate check points to ensure that all subsystems are functioning according to the design specifications. Malfunction, when occurring, will be thoroughly investigated. If the malfunction is determined to be caused by subsystem interaction, the subsystem that caused the malfunction may be redesigned.

9.4.2.4.3 Program Requirements. The test article will be the complete integrated system. Recording methods and recording equipment will be the same as those to be used in the qualification tests (paragraph 9.4.2.1.3).

9.4.2.4.4 Equipment. Equipment will be the same as the equipment to to used for the qualification tests (paragraph 9.4.2.1.4), less environmental chambers.

9.4.2.4.5 Facilities. Facilities will be the same as the facilities to be used for the subsystem tests (paragraph 9.4.2.3.5).

9.4.2.4.6 Test Schedule. The integrated system test schedule is shown in Figure 9-5.

[redacted]

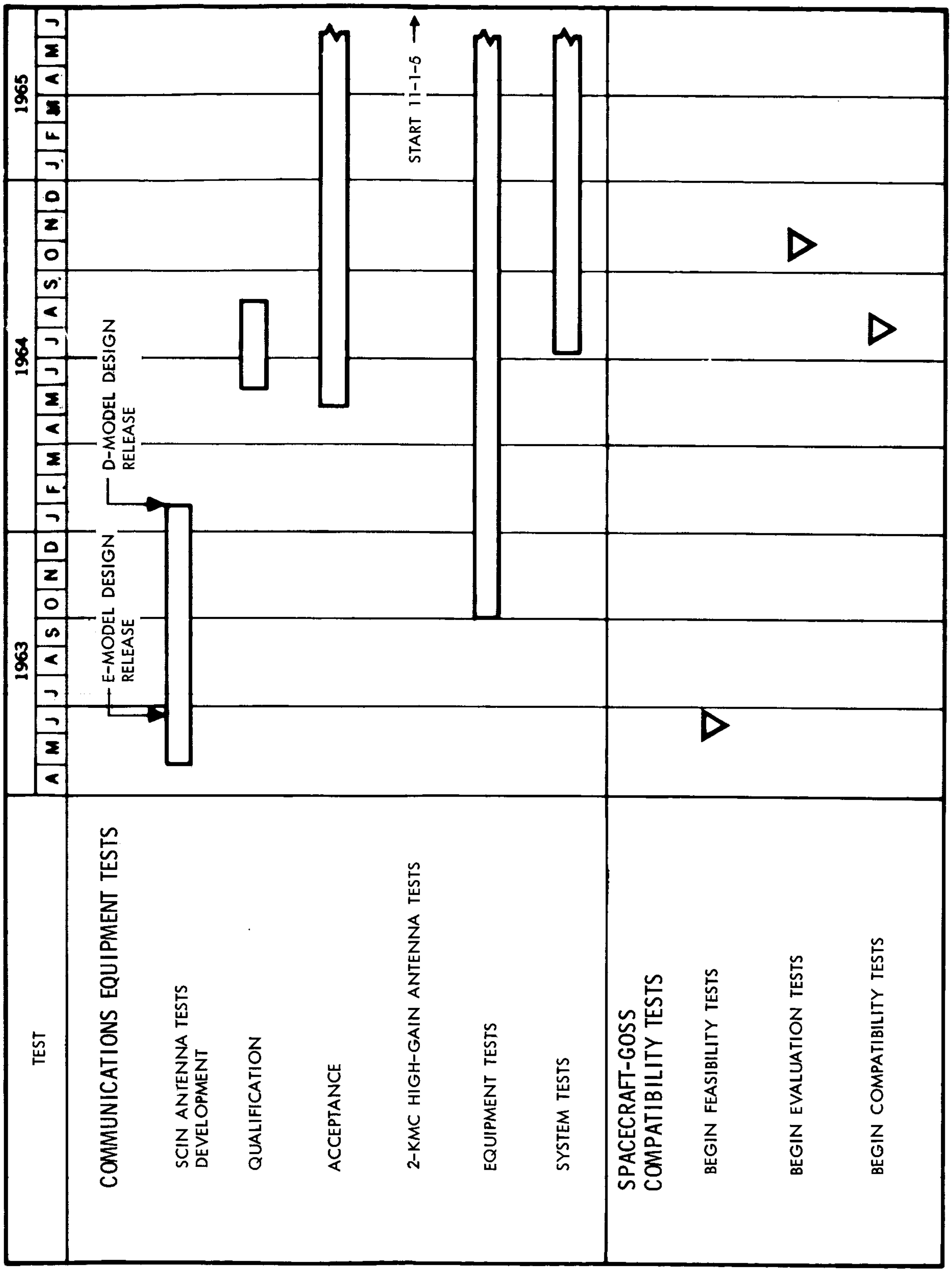

Figure 9-5. S&ID Communications System and Spacecraft GOSS Compatibility Test Schedules

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10.0 CREW SYSTEMS*

10.1 SCOPE

This section comprises an outline of crew systems development design evaluation and qualification tests to be accomplished during Apollo system development, qualification, and flight test. The intent of this test plan is to specify test requirements for determination of equipment, facilities, and test scheduling and for integration of crew systems test requirements into the over-all test program. Detailed test plans will be provided by Crew Systems, as required, to implement the general test plan contained in this document.

The crew systems test plan is divided into two major program areas as follows:

1. Crew equipment and systems test program (engineering evaluation and qualification of Apollo system man-machine, human engineering, and environmental interfaces) (See paragraph 10.2.)

2. Crew engineering and environmental simulation test program (evaluation and qualification of the interactive effects of human performance and systems performance) (See paragraph 10.3.)

In addition, crew systems developmental test requirements concerning flight-drop and launch tests will be integrated into the multiple systems test programs for development and design proofing.

10.2 CREW SYSTEMS AND EQUIPMENT TEST PROGRAM

Crew systems and equipment tests will be conducted to evaluate crew equipment, spacecraft systems, and related GSE systems man-machine, human engineering, and environmental interface designs. Initial tests will be conducted to evaluate crew systems design concepts and functions and to obtain an early insight into problem areas or deficiencies of the man-machine relationships. Design evaluation tests will begin prior to the preliminary drawing release. Testing will progress from breadboard equipment models installed in mock-ups and simulators and will continue throughout design development in the house spacecraft, during major ground tests, boilerplate

*Entire section reissued

tests, and the flight-test programs. To facilitate identification of specific test requirements, the crew system design evaluation program is divided into equipment and systems test categories: crew equipment tests and spacecraft (crew) systems interface tests.

10.2.1 Crew Equipment Tests

The crew equipment provisions that are to be evaluated will include the following:

Crew support (couch and shock attenuation) system
Restraint system
Pressure garment assembly interfaces
Food and water provisions
Crew equipment and accessories
Survival equipment
Biomedical equipment and provisions
Waste management system (See paragraph 10.2.2.)

10.2.1.1 Crew Support (Couch and Shock Attenuation) Systems Tests

Crew support systems tests will be conducted in two concurrent test areas, consisting of (1) human engineering tests and (2) dynamic tests. Laboratory tests will be conducted and monitored for all equipment.

10.2.1.1.1 Human Engineering Tests.

10.2.1.1.1.1 Objectives. Tests will be conducted to verify the design of the crew couch suspension and restraint system for conformance with crew systems human engineering design criteria (S&ID and NASA specifications) and to verify integration and interface compatibility of associated crew equipment items.

10.2.1.1.1.2 Test Requirements.

1. Anthropometrics. Verify dimension, with weight and center-of-gravity locations, for all major components of the couch. Verify couch contour and design for compatibility and fit with human anatomy. Determine and evaluate visual and functional reach envelopes with human subject (10 through 90 percentile) in relation to couch and restraint system design. Obtain camera coverage for documentation.

2. Crew Interchangeability. Evaluate couch and restraint system design for crew interchangeability. Conduct tests with appropriate

combinations of human subjects (10 through 90 percentile). Evaluate couch and restraint systems attachments and adjustments for ease of operation. Obtain motion picture and time-history data for evaluation and permanent record.

3. Attachment, Adjustment, and Release. Conduct tests with human subjects (10 through 90 percentile) to evaluate functionally the combined couch and restraint systems for attachment, adjustment, and release capabilities. Record deficiencies or problems encountered for design improvement. Obtain time-motion picture coverage and time-history data for evaluation and permanent record, as required.

4. System Compatibility. Verify compatibility of crew couch and restraint system with pressure garment assembly, personal clothing and accessories, and any other related equipment or couch attaching structure. Conduct functional and operational tests for evaluation of systems interaction (interference, accessibility, maintainability, and characteristic performance). Obtain documentary photographs for analysis and record, as required.

5. Comfort. Evaluate human comfort tolerance levels for full body and head support. Evaluate all couch and body positions. Conduct tests within the duration and environmental parameters typical for the Apollo missions. Determine any deficiencies or problems regarding degree of comfort, localized high-pressure bearing locations, and associated time factors.

6. Crew Capability. Verify design for crew capability of ingress and egress into crew couch and restraint system. Conduct tests for all conditions of ingress and egress, including prelaunch, in-flight, zero-G, and postlanding emergency egress. Recapitulate action and time histories of the tests with lapsed-time camera coverage.

10.2.1.1.1.3 Equipment Requirements. Human engineering tests of the couch suspension and restraint systems will require human test subjects equipped with pressure suits and related items of personal equipment. The test subjects' performances will be recorded by stop watch, time-motion camera, and still photography. Provisions must be made for pressurizing and venting the pressure suits. Intercommunication between test subjects and test operations personnel will be required.

10.2.1.1.1.4 Facilities. Developmental and engineering design tests will be conducted at Downey, using Apollo development mock-ups 2 and 18 and the ECS breadboard test facility, house spacecraft 1. Qualification tests will be conducted in the house spacecraft, Airframe 006, and in conjunction with the environmental proof test program, Airframe 008.

10.2.1.1.2 Dynamic Tests.

10.2.1.1.2.1 Objectives. Dynamic tests will be conducted to evaluate the crew couch, suspension, and restraint system full body and head support design for all Apollo nominal and emergency acceleration, impact, vibration, and acoustical profiles. Evaluate histories of accelerations, impact, and vibration loads imposed on crew members and critical structure of the couch.

10.2.1.1.2.2 Test Requirements. Tests will be conducted as follows:

1. Land and Water Impact Tests. Crew support (couch and shock attenuation) system drop tests will verify that Apollo crew members will not be subjected to impact acceleration loads in excess of human tolerance limits. These tests will be conducted concurrently and in conjunction with the landing impact and stability test program. (See Section 12.0.)

   Anthropomorphic dummies (10, 50, and 90 percentile) will be secured in the support system couches with the restraint systems. Associated items of crew equipment will be included in the tests.

   The weight and center of gravity for each couch-dummy combination will be ascertained prior to each test to assist in evaluating impact acceleration loads imposed on the attenuation devices and to obtain data for center-of-gravity management.

   Tests will be conducted with various combinations of dummy sizes and seat arrangements, including loadings of less than three crewmen to cover the cases of one or two crewmen lost during lunar operations. The command module will be dropped with various combinations of vertical and horizontal velocities and various command module orientations.

   Tri-axial accelerometers will be installed in the dummy's chest, in the head (SCIP instrumentation), on the couch, and on the command module floor structure. Couch measurements will be used for appraising Apollo capability in meeting NASA-defined human tolerance limits. The time histories of accelerations will be recorded. High-speed motion picture coverage will record the dynamic action for analysis and permanent record. Boilerplates 1, 2, and 28 and Airframe 005 and 007 will be used for the land and water impact tests.

2. Vibration Tests. The crew support system will be tested to verify the following:

   a. That the vibrational response of the crew support system, mounted on the shock attenuation and suspension system, does not exceed the designated vibration limits when the system is subjected to vibrational parameters anticipated for the command module during mission phasing in which there is high vibration (such as launch, booster separation, and reentry).

   b. That the characteristic vibrational environment for the crew does not exceed the physiological tolerance limits and the human psychophysical factors necessary to perform operational and task requirements for all phases of the Apollo mission. These performance determinations will be carried out on all crew-operated systems that are used during vibration periods.

Anthropomorphic dummies will be secured in the couch with the restraint system for proof loading prior to testing with subjects. The couch and shock attenuation system will be mounted on the vibration table in a test fixture representative of the command module interior installation. Tri-axial accelerometers will also be mounted on the couch and on the vibration table. The time histories of all accelerometers will be recorded simultaneously. The general vibration test procedure specified in MIL-STD-810 will be followed, except that the vibrational parameters (frequency, amplitude, G's, and time duration) will be commensurate with the anticipated level for a typical Apollo mission.

Performance tests will be performed with human subjects (10 through 90 percentile) equipped with full pressure suits to verify the requirements of (b) above and to obtain comparative data for possible correlation during dummy runs on emergency profiles considered unsafe for human exposure. Instrumentation and sensors will be provided to monitor human psychophysical factors and physiological response.

The human subjects must be able to monitor displays and perform tasks satisfactorily during representative vibrations to assure the safety of the Apollo mission. These tests will be repeated if, after early mission launches, the vibrational response of the command module is more severe than the tested response.

The qualification vibration test program will be conducted in conjunction with, and as part of, the Airframe 006 vibration part of the environmental proof test program (see Volume V, Section 6.0).

3. Centrifuge Tests. The crew support (couch, suspension, and restraint) system will be fixture mounted and tested in a centrifuge to verify that the sustained acceleration profiles imposed on the crew members do not exceed the physiological tolerance limits and human psychophysical factors necessary to perform operational task requirements necessary for all phases of the Apollo mission.

The tests will be conducted with human subjects (10 through 90 percentile) to verify the preceding requirement. Prior to the conduct of tests with human subjects, the crew support system will be proof tested to a sustained acceleration of 1.5 times that of the mission profile. The subjects will be equipped with pressure suits, pressurized and unpressurized, and will perform simulated duty tasks while being subjected to sustained acceleration profiles representative of the various phases of the Apollo mission.

A couch will be mounted on a centrifuge gondola representative of a portion of the Apollo cabin interior configuration. Bio-medical instrumentation will be mounted on the test subject. Force-link sensors will be installed on the restraint system. Time histories of the acceleration and forces will be recorded as the crew support system is subjected to various sustained acceleration profiles of the Apollo mission.

Complete data on crew abilities in the manual mode will be collected during acceleration. Two television cameras will be located to monitor continuously the couch and subject response. Equipment will be provided for pressurizing the pressure suits. Boilerplate crew couches will be used until spacecraft items are available. These tests will be conducted concurrently with, and as part of, the dynamic base simulation program. (See paragraph 10.3.)

4. Flight Tests. The crew support system will be evaluated on the basis of data obtained during the flight test program to verify that acceleration and vibration loads do not exceed human tolerance limits.

   The crew support and attenuation systems will be evaluated by astronaut reports during Airframe 011 and 012 flights.

10.2.1.1.3 Equipment Requirements. Instrumented anthropomorphic dummies will be required for the land and water impact test programs and for Airframe 002 and 010 flight tests. Human subjects with pressure suits will be required for the centrifuge and also for the vibration test program.

Instrumentation requirements for monitoring the flight test program are specified in Volume V, Multiple Systems Tests.

10.2.1.1.4 Facilities. Facilities requirements are as follows:

1. Land and Water Impact Tests. S&ID facilities will be used.
2. Vibration Tests. S&ID facilities will be used.
3. Centrifuge Tests. Johnsville centrifuge facility will be used.
4. Flight Tests. See Volume V, Multiple Systems Tests.

10.2.1.1.5 Test Schedules. For the test schedule, see Figure 10-1.

10.2.1.2 Restraint System Tests

10.2.1.2.1 Objectives. The objectives of the restraint system tests will be to verify the design of the restraint harness as follows:

1. Each crew support system will use a restraint harness to protect the Apollo crew members from acceleration and vibration loads imposed during Apollo nominal, nonstressed, and emergency conditions. The restraint system will also have retention capabilities to support the crew in a manner which will enable or assist them in performing their required tasks during these stressed and emergency conditions.

2. The design of the restraint system will be compatible with the design of the crew couch, pressure suit, and other adjacent or related equipment.

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10.2.1.2.2 Test Requirements.

10.2.1.2.2.1 Subcontractor Tests. The supplier shall have or will establish a program that conforms to the requirements of the S&ID quality control specification. S&ID reserves the right to conduct engineering, reliability, quality control, and other surveys as may be deemed necessary to evaluate adequately the supplier's capabilities. Subcontractor tests shall be classified as development, qualification, and acceptance tests.

1. Development Tests. The supplier shall perform adequate tests during development to determine that the materials and design approach are compatible with the requirements of the procurement specification. The development tests shall be specified by the supplier and subject to approval by S&ID.

2. Qualification Tests. Qualification tests are conducted to verify that the design and performance requirements of the procurement specification have been met. The tests shall be performed on items produced with the same tooling and processes and under the same conditions as those intended for quantity production. It shall be the responsibility of the supplier to remedy all deficiencies revealed in the qualification tests.

    a. Humidity. The unpackaged harness assembly shall be subjected to the humidity test specified in Standard MIL-STD-810, Method 507, Procedure I. At the completion of the test, the harness assembly shall be examined for signs of deterioration.

    b. Vacuum Exposure. The harness assembly shall be placed within a vacuum chamber and the pressure reduced to 1×10^{-4} mm of mercury. This condition shall be maintained for a period of 100 hours. During the first 35 hours, the temperature shall be maintained at 150±5 F. During the next 35 hours, the temperature shall be reduced to 75±5 F and maintained. The temperature shall be reduced to 0±5 F and maintained during the remaining 30 hours. At completion of the test, the harness assembly shall be examined for signs of deterioration.

    c. Oxygen Exposure. The harness assembly shall be placed within a chamber and exposed to a relative humidity of 95±5 percent in an otherwise commercially pure oxygen atmosphere at 5 psia. This condition shall be maintained

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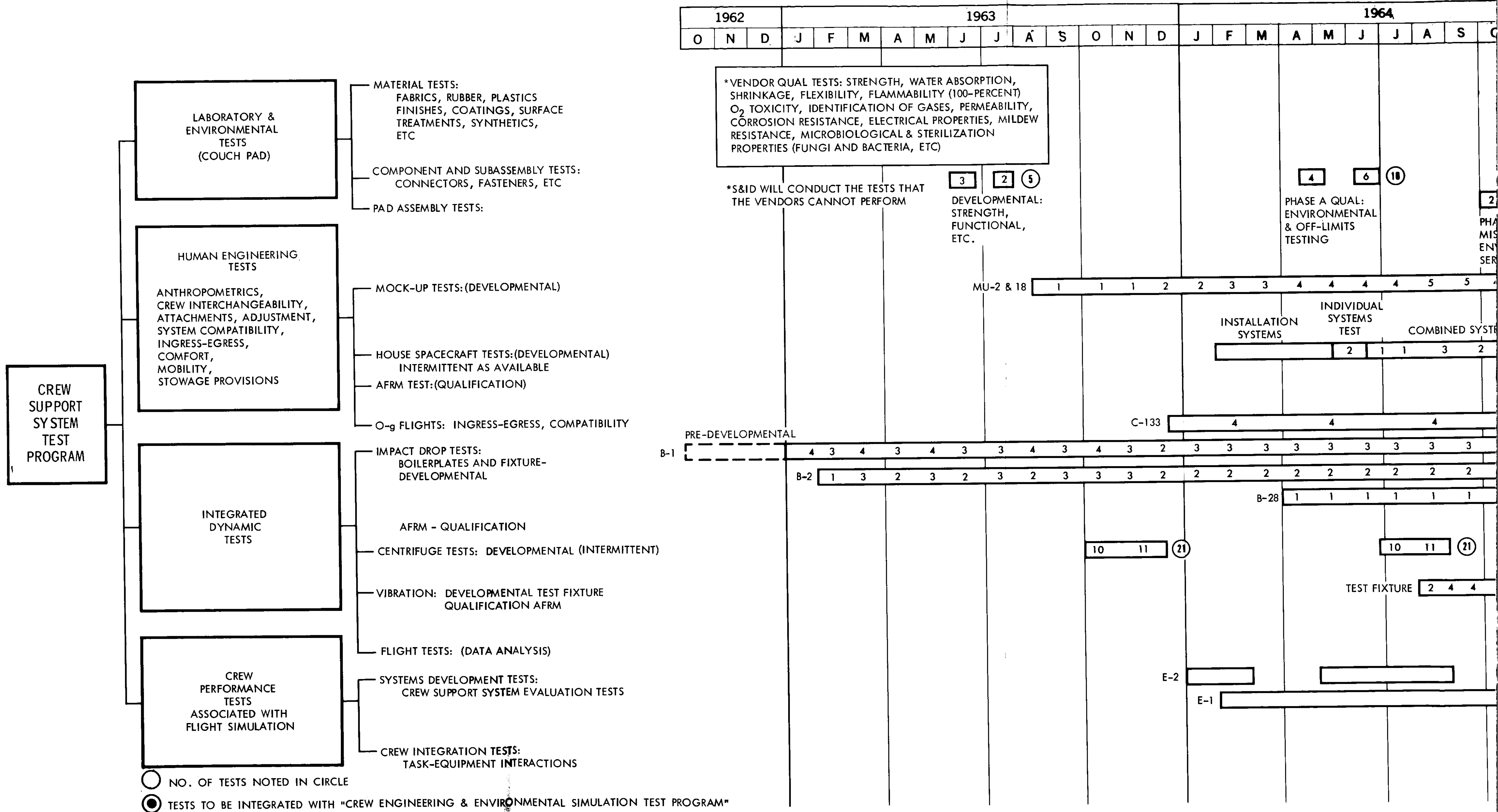
CREW SUPPORT SYSTEM TEST PROGRAM
LABORATORY & ENVIRONMENTAL TESTS (COUCH PAD)
MATERIAL TESTS: FABRICS, RUBBER, PLASTICS FINISHES, COATINGS, SURFACE TREATMENTS, SYNTHETICS, ETC
COMPONENT AND SUBASSEMBLY TESTS: CONNECTORS, FASTENERS, ETC
PAD ASSEMBLY TESTS:
HUMAN ENGINEERING TESTS
ANTHROPOMETRICS, CREW INTERCHANGEABILITY, ATTACHMENTS, ADJUSTMENT, SYSTEM COMPATIBILITY, INGRESS-EGRESS, COMFORT, MOBILITY, STOWAGE PROVISIONS
MOCK-UP TESTS: (DEVELOPMENTAL)
HOUSE SPACECRAFT TESTS: (DEVELOPMENTAL) INTERMITTENT AS AVAILABLE
AFRM TEST: (QUALIFICATION)
O-g FLIGHTS: INGRESS-EGRESS, COMPATIBILITY
INTEGRATED DYNAMIC TESTS
IMPACT DROP TESTS: BOILERPLATES AND FIXTURE-DEVELOPMENTAL
AFRM - QUALIFICATION
CENTRIFUGE TESTS: DEVELOPMENTAL (INTERMITTENT)
VIBRATION: DEVELOPMENTAL TEST FIXTURE QUALIFICATION AFRM
FLIGHT TESTS: (DATA ANALYSIS)
CREW PERFORMANCE TESTS ASSOCIATED WITH FLIGHT SIMULATION
SYSTEMS DEVELOPMENT TESTS: CREW SUPPORT SYSTEM EVALUATION TESTS
CREW INTEGRATION TESTS: TASK-EQUIPMENT INTERACTIONS
NO. OF TESTS NOTED IN CIRCLE
TESTS TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENTAL SIMULATION TEST PROGRAM"
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1963
1964
O N D J F M A M J J A S O N D J F M A M J J A S
*VENDOR QUAL TESTS: STRENGTH, WATER ABSORPTION, SHRINKAGE, FLEXIBILITY, FLAMMABILITY (100-PERCENT) O_2 TOXICITY, IDENTIFICATION OF GASES, PERMEABILITY, CORROSION RESISTANCE, ELECTRICAL PROPERTIES, MILDEW RESISTANCE, MICROBIOLOGICAL & STERILIZATION PROPERTIES (FUNGI AND BACTERIA, ETC)
*S&ID WILL CONDUCT THE TESTS THAT THE VENDORS CANNOT PERFORM
3 2 5
DEVELOPMENTAL: STRENGTH, FUNCTIONAL, ETC.
4 6 18
PHASE A QUAL: ENVIRONMENTAL & OFF-LIMITS TESTING
MU-2 & 18
1 1 1 2 2 3 3 4 4 4 4 5 5
INSTALLATION SYSTEMS
INDIVIDUAL SYSTEMS TEST
COMBINED SYST
2 1 1 3 2
C-133
4 4 4
PRE-DEVELOPMENTAL
B-1
4 3 4 3 4 3 3 4 3 4 3 2 3 3 3 3 3 3 3 3 3
B-2
1 3 2 3 2 3 2 3 3 3 2 2 2 2 2 2 2 2 2 2
B-28
1 1 1 1 1 1
10 11 21
10 11 21
TEST FIXTURE
2 4 4
E-2
E-1

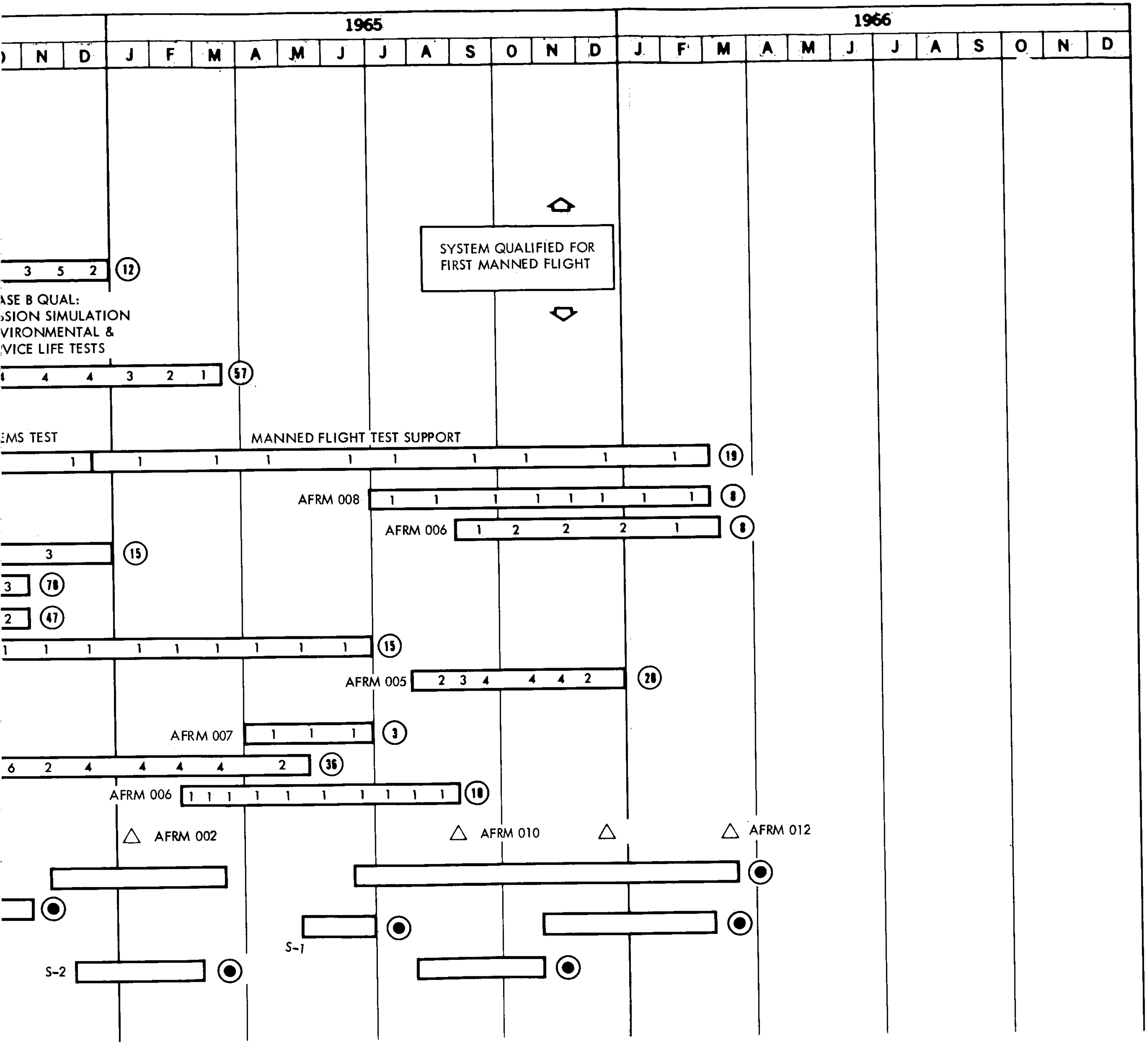

Figure 10-1. Systems Approach—Crew Support System Test Program

for a period of 336 hours. The temperature during the first 36 hours shall be 150±5 F and 75±5 F for the remaining 300 hours. At completion of test, the harness assembly shall be examined for signs of deterioration.

d. Functional Test (Chest Release Hardware). Each one-point release unit shall be functionally tested. The specified number of restraining straps shall be attached to this quick release unit. The following tensile forces shall be applied simultaneously: 900 pounds to the shoulder harness straps and inertia reels, 3,000 pounds to the chest straps, and 1,800 pounds to the crotch strap with inertia reel. The load on each strap shall then be reduced to 5 pounds, and the quick release unit shall be actuated. This test cycle shall be repeated a total of 100 times without failure, deformation, or damage. At the completion of the tests, the quick release unit shall be examined for wear, deformation, or damage.

e. Functional Test (Lap Belt Release Hardware). Each lap belt release unit shall be functionally tested. The specified number of straps shall be attached to the release unit, and a tensile force of 4,000 pounds shall be applied simultaneously to each strap. The load on each strap shall then be reduced to 5 pounds, and the release unit shall be actuated. This test shall be repeated 100 times. Upon completion of these tests, the release unit shall be examined for wear, deformation, or damage.

f. Ultimate Load. The proof loading test of paragraph 3b shall be repeated, except that the tensile load is to be applied and increased until failure of any part of the harness occurs. Details of the failure shall be recorded.

g. Proof Loading, Simulated Use. Each harness shall be assembled in a testing machine with anthropomorphic dummy in a simulated couch fixture; the dummy and couch fixture are to be furnished by S&ID. The harness shall be assembled in the testing machine so that the applied load is transmitted to the harness in a manner simulating actual usage. The load shall be applied at the rate of 6000 pounds per minute until a static load of

[redacted]

4000 pounds is obtained. There shall be no signs of weakening of the webbing or stitching, slippage of the webbing through the hardware, or deformation of the metal fitting.

3. Acceptance Tests. Prior to delivery and as a condition of acceptance, the supplier shall subject each harness assembly to the following acceptance tests. S&ID reserves the option to reconduct any or all of the acceptance tests specified herein.

   a. Examination of Product. Each harness assembly shall be subjected to a visual and dimensional inspection to determine compliance with the requirements specified herein in respect to materials, construction, workmanship, dimensions, designs, and performance.

   b. Proof Loading. All webbing and joints and other fastening devices of the harness assembly shall be subjected to a tensile load of 2000 pounds. There shall be no signs of weakening of the webbing and stitching or deformation of the hardware.

   c. Acceleration. The harness assembly shall be subjected to acceleration forces that result in a sinusoidal curve with the maximum acceleration of 20 G over a period of 120 seconds in six opposite directions. A weight that simulates the thoracic weight of a 95-percentile man shall be retained in the test fixture while the forces are being applied. There shall be no signs of weakening in the webbing and stitching or deformation of the hardware.

10.2.1.2.2.2 S&ID Test Program.

1. Human Engineering Tests. Human engineering design evaluation tests will be conducted concurrently with, and as a part of, the human engineering test program for the crew support system. (See paragraph 10.2.1.1.1.)

2. Dynamic Tests. The characteristic performance capabilities of the restraint system during nominal, nonstressed, and emergency loading conditions will be evaluated concurrently with, and as part of, the dynamic test program for the crew support system. (See paragraph 10.2.1.1.2.) Fail-safe testing will be conducted to determine adequacy of hardware mechanization to lock safely under all loads expected.

[redacted]

10.2.1.2.3 Equipment and Facilities. Materials tests and static structural tests will be conducted at the S&ID Engineering Development Laboratory facilities. The human engineering and dynamic tests of the restraint system will be conducted as part of the crew support system test program described in paragraph 10.2.1.1.

10.2.1.2.4 Test Schedule. The restraint system test schedule is shown in Figure 10-2.

10.2.1.3 Pressure Garment Assembly Interface Tests

10.2.1.3.1 Test Requirements.

10.2.1.3.1.1 Associate Contractor Tests. Developmental tests for the pressure suit assembly will be conducted by the NASA associate contractor as directed by NASA. Crew Systems will monitor major test milestones and will coordinate those tests which reflect interface with the Apollo vehicle.

10.2.1.3.1.2 Apollo Integration Tests. S&ID is charged with integration of the pressure suit assembly with the vehicle and will conduct a continuous program leading from early prototypes to final qualification and first flight assemblies. (See SID 62-1003, NASA-Furnished Crew Equipment Interface Requirements Specification.)

10.2.1.3.1.2.1 Human Engineering Tests.

1. Dimension and tariff of pressure garment assembly components will be verified against the actual anthropometric range of Apollo personnel for interface with the C/M interior configuration. This includes the pressure garment assembly and special overgarments in conjunction with the crew couch and restraint system. Both pressurized and unpressurized determinations will be made.

2. Tests will be conducted to determine pressurized and unpressurized pressure garment assembly kinetics for interface with the cabin interior configuration. Maximum reach, functional reach, and visual envelopes will be evaluated for orbital, reentry, and emergency acceleration profiles, as well as donning and doffing time and space requirements with relation to the 5-minute flood flow duration.

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[redacted]

[redacted]

3. Comfort will be empirically evaluated in terms of the mission environmental parameter duration and limitations noted for subsequent design compensation. This investigation will be concurrent with the crew support system test program. (Refer to paragraph 10.2.1.1.) The influence of acceleration, vibration, impact, acoustical, and thermal envelopes predicted for the Apollo mission represent primary influences which will be considered with reference to the pressure suit assembly and will complement the human engineering portions of the study.

10.2.1.3.1.2.2 System Compatibility Tests. Human testing will quantitatively and qualitatively evaluate the interactions of the pressure garment assembly and environmental control system interfaces with the crew couch and restraint system interfaces. Additional performance tests will evaluate biosensor compatibility, personal communications interface, stowage provisions for the portable life support system (PLSS), operation, and storage provisions for the pressure garment assembly. Such testing will be reflected in essentially all of the crew engineering and environmental simulation program and will be integrated with the ECS system during the ECS breadboard manned test program. (See Section 5.0)

10.2.1.3.2 Equipment and Facilities. The space suit assembly is a basic requirement for virtually all phases of the crew systems human engineering, crew performance, and flight simulation programs. Equipment and facilities necessary for the over-all program are reflected in Figure 10-3. Human subjects, anthropometric dummies, suit support consoles, and physiological instrumentation will be required throughout all crew systems testing in conjunction with medical support in order to effect the scope of investigation.

10.2.1.3.3 Test Schedule. The test schedule and chronology of the pressure suit assembly interface tests are shown in Figure 10-3.

10.2.1.4 Food and Water Provisions Interface Tests

10.2.1.4.1 Objectives. Major emphasis will be directed toward the ECS breadboard tests for metabolic acceptability determinations and the Airframe 006 and Airframe 008 tests for confirmation of systems adequacy. Basic commodities of food and water will be tested in context with spacecraft preparation equipment and the metabolic needs of the crew as applied to the various anticipated Apollo missions. Such an endeavor requires an intimate interface with the man in the loop and the acquisition of sufficient quantitative information to validate the system. Items to be tested include the following:

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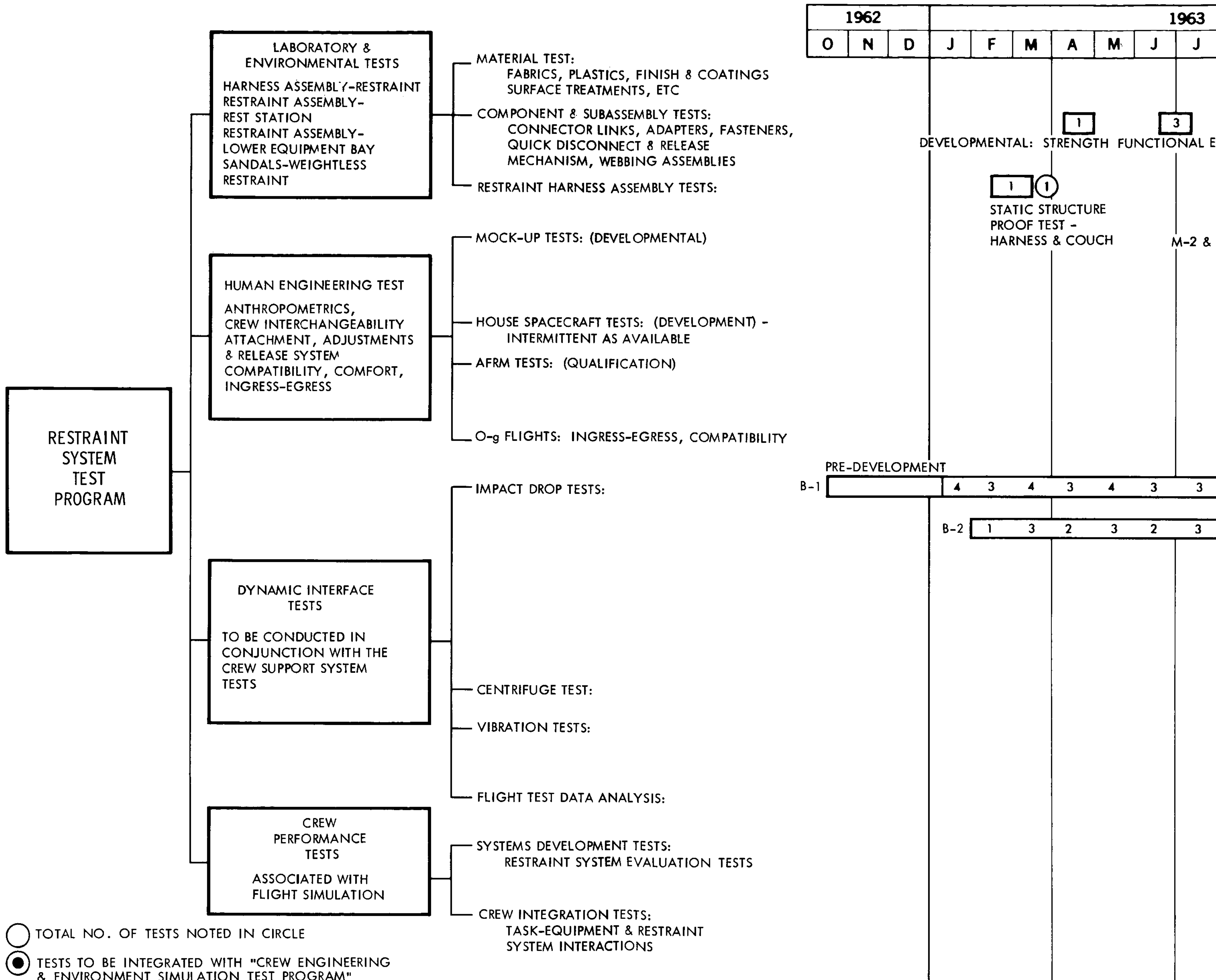

RESTRAINT SYSTEM TEST PROGRAM
LABORATORY & ENVIRONMENTAL TESTS
HARNESS ASSEMBLY-RESTRAINT
RESTRAINT ASSEMBLY-REST STATION
RESTRAINT ASSEMBLY-LOWER EQUIPMENT BAY
SANDALS-WEIGHTLESS RESTRAINT
MATERIAL TEST:
FABRICS, PLASTICS, FINISH & COATINGS
SURFACE TREATMENTS, ETC
COMPONENT & SUBASSEMBLY TESTS:
CONNECTOR LINKS, ADAPTERS, FASTENERS,
QUICK DISCONNECT & RELEASE
MECHANISM, WEBBING ASSEMBLIES
RESTRAINT HARNESS ASSEMBLY TESTS:
HUMAN ENGINEERING TEST
ANTHROPOMETRICS,
CREW INTERCHANGEABILITY
ATTACHMENT, ADJUSTMENTS
& RELEASE SYSTEM
COMPATIBILITY, COMFORT,
INGRESS-EGRESS
MOCK-UP TESTS: (DEVELOPMENTAL)
HOUSE SPACECRAFT TESTS: (DEVELOPMENT) -
INTERMITTENT AS AVAILABLE
AFRM TESTS: (QUALIFICATION)
O-g FLIGHTS: INGRESS-EGRESS, COMPATIBILITY
DYNAMIC INTERFACE TESTS
TO BE CONDUCTED IN CONJUNCTION WITH THE CREW SUPPORT SYSTEM TESTS
IMPACT DROP TESTS:
CENTRIFUGE TEST:
VIBRATION TESTS:
FLIGHT TEST DATA ANALYSIS:
CREW PERFORMANCE TESTS
ASSOCIATED WITH FLIGHT SIMULATION
SYSTEMS DEVELOPMENT TESTS:
RESTRAINT SYSTEM EVALUATION TESTS
CREW INTEGRATION TESTS:
TASK-EQUIPMENT & RESTRAINT
SYSTEM INTERACTIONS
1962
1963
O N D J F M A M J J
1
3
DEVELOPMENTAL: STRENGTH FUNCTIONAL E
1
1
STATIC STRUCTURE
PROOF TEST -
HARNESS & COUCH
M-2 &
PRE-DEVELOPMENT
B-1
4 3 4 3 4 3 3
B-2
1 3 2 3 2 3
TOTAL NO. OF TESTS NOTED IN CIRCLE
TESTS TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENT SIMULATION TEST PROGRAM"

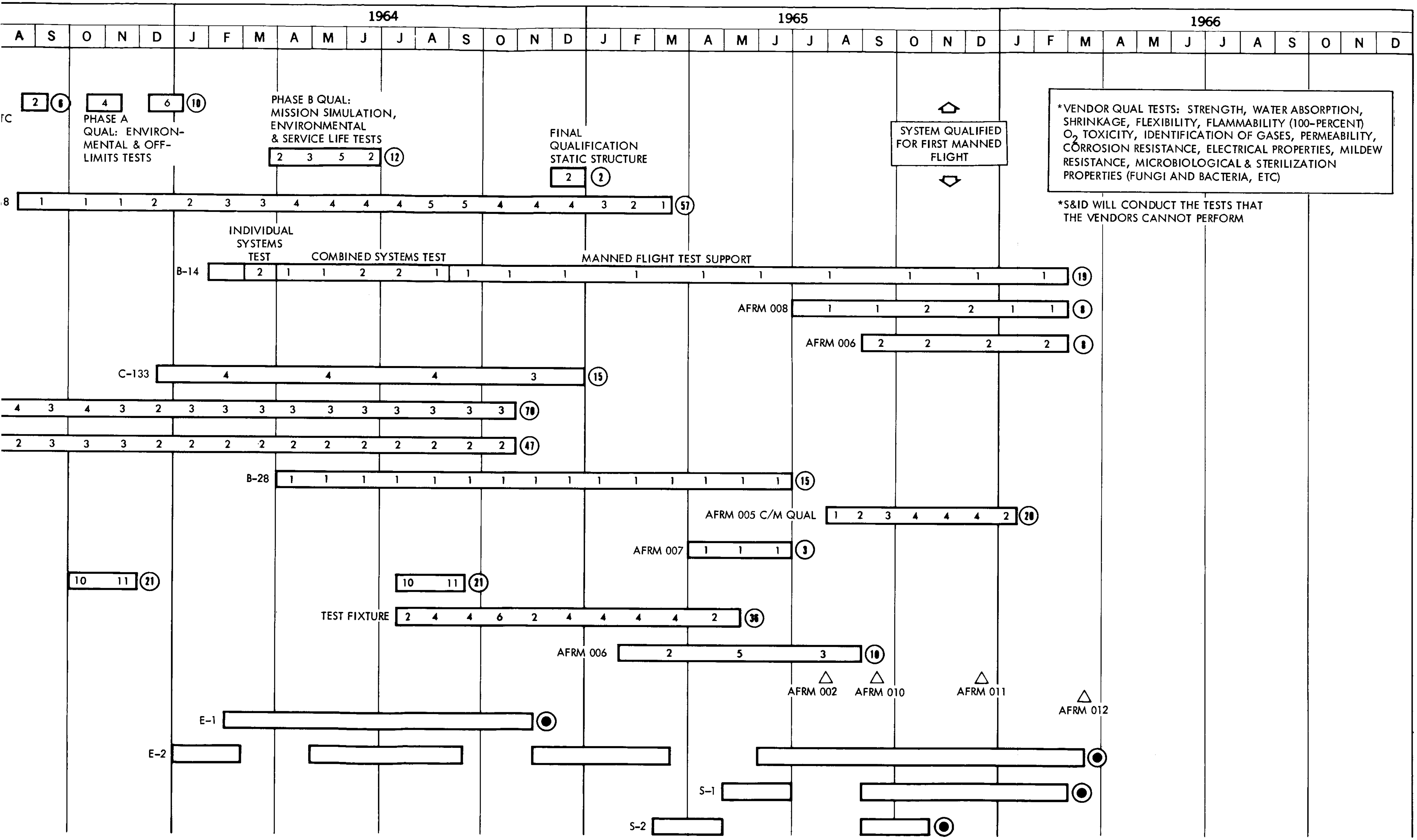

Figure 10-2. Systems Approach—Crew Restraint System Test Program

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M-2 & 18

- PRESSURE GARMENT ASSEMBLY INTERFACE PROGRAM
  - HUMAN ENGINEERING TESTS:
    - ANTHROPOMETRIC
      - SUIT WEIGHT, DIMENSIONS, & TARIFF
      - COUCH-RESTRAINT INTERACTIONS
    - MOBILITY
      - CABIN INTERIORS REACH RELATIONSHIPS
      - VISUAL FIELD
      - COMMAND MODULE MOBILITY
      - INGRESS-EGRESS-AIRLOCK MOVEMENT
      - DONNING & DOFFING
    - COMFORT
      - COUCH RESTRAINT COMPATIBILITY
      - ENVIRONMENTAL PARAMETERS
    - MOCK-UP TESTS: DEVELOPMENTAL
    - HOUSE SPACECRAFT:
    - AFRM TESTS: (QUALIFICATION)
  - SYSTEM FUNCTIONAL TESTS:
    - ECS INTERFACE TESTS
      - TEMPERATURE DISTRIBUTION
      - ATMOSPHERIC COMPOSITION
      - TOTAL PRESSURE & SYSTEM RESPONSE TO CABIN PUNCTURE
      - SUIT INTERFACES
      - CO_2 & TOXIC CONTAMINANT REMOVAL
    - BIOMEDICAL INSTRUMENTATION
    - STORAGE & PLSS OPERATION
    - FLIGHT CONTROL INTERACTION
    - CREW PERFORMANCE TESTS: (INTEGRATE WITH SIMULATED TEST PROGRAM)
    - CENTRIFUGE TESTS:
    - CREW SUPPORT SYSTEMS INTERFACE: (SEE CREW SUPPORT SYSTEMS TEST PROGRAM)
    - ECS VERIFICATION TESTS:
      - ECS BREADBOARD TESTS
      - VIBRATION, ACOUSTICAL NOISE, HIGH VACUUM, & TEMPERATURE

○ TOTAL NO. OF TESTS NOTED IN CIRCLE

◉ TESTS TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENTAL SIMULATION TEST PROGRAM"

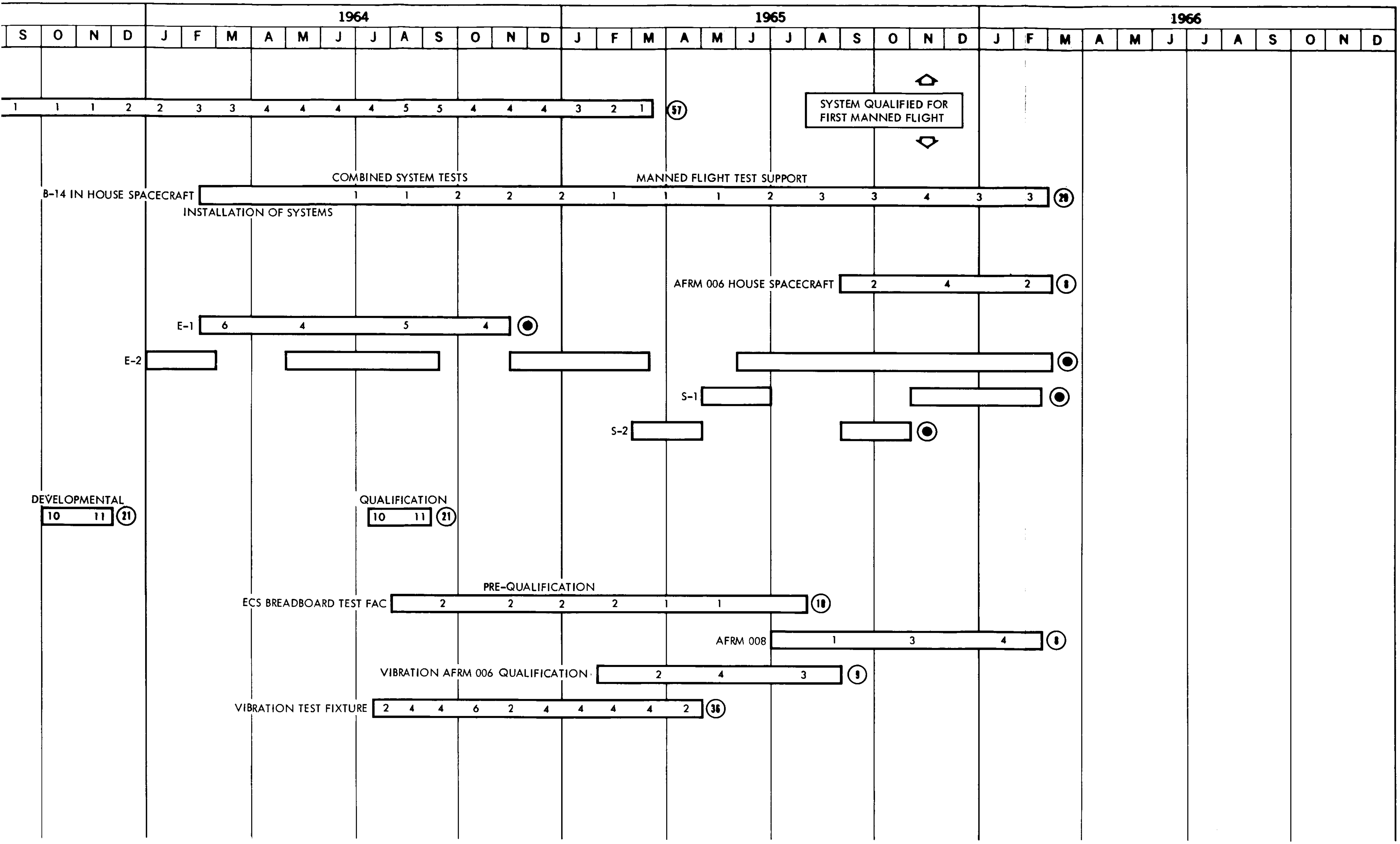

Figure 10-3. Systems Approach—Pressure Garment Assembly Interface Test Program

Food (GFP)
Package set, food (GFP)
Mouthpiece, food, personal (CFE)
Delivery assembly, water provisions (CFE)
Shelf assembly, work, food preparation (CFE)
Compartment door assembly, work, food (CFE)

10.2.1.4.2 Test Requirements.

10.2.1.4.2.1 Associate Contractor Tests (GFE). Developmental tests for food and water provisions will be conducted by the NASA associate contractor as directed by NASA, Crew Systems will monitor major test milestones and will coordinate those tests that will reflect interface with the Apollo vehicle.

10.2.1.4.2.2 Subcontractor Tests (CFE). The suppliers shall have or will establish a program that conforms to the requirements of MQ 0802-001 for quality control. NAA-S&ID reserves the right to conduct engineering, reliability, quality control, and other surveys as may be deemed necessary to evaluate adequately the capabilities of the suppliers. Subcontractor tests to be performed shall be classified as development, qualification, and acceptance tests.

1. Development Tests. The supplier shall perform adequate tests during development to determine that the materials and design approach are compatible with the requirements of the procurement specification. The development tests shall be specified by the supplier and will be subject to the approval of S&ID.

2. Qualification Tests. Qualification tests shall be conducted to verify that the design and performance requirements of the procurement specification have been met. The tests shall be performed on items produced with the same tooling and processes and under the same conditions as those intended for quantity production. Qualification criteria shall be those specified for ground qualification tests. (Refer to Volume III.)

3. Acceptance Tests. Prior to delivery and as a condition of acceptance, the provisions of Volume IV, Acceptance Test Plan, shall apply.

10.2.1.4.2.3 Apollo Integration Tests. S&ID is charged with integration of food and water provisions with the space vehicle and will conduct a continuous program leading from early prototypes to final qualification and first flight assemblies. (Refer to SID 62-1003, NASA-Furnished Crew Equipment Interface Requirements Specification)

1. Food System Evaluation. Testing will be performed to verify storage and preparation in terms of Apollo design criteria. Valid data on such parameters will be gained through mission duration studies extending over several days.

2. Food Container Design. Dimensions, storage, and biomechanics will be developed through extensive evaluator, simulator, and weightlessness trials in cooperation with the customer. Compatibility with the food preparation system will be assured, and time-line analysis will be conducted to establish relationship with routine and emergency crew function.

3. Water System Evaluation. Tests of the water system will be conducted to verify conformance with S&ID and NASA human engineering design criteria. Water quantity, potability, and temperature control will be evaluated in conjunction with necessary food preparation activities during the crew engineering simulation test program (paragraph 10.3). A primary system effort will be expended in continuous evaluation of the water quantity versus metabolic and ECS requirements. Survival requirements will be verified to reflect fuel cell water, in addition to container supplies, and will be sufficient for any post-landing situation.

4. Drinking Container Design. Human engineering tests will be conducted for the purpose of confirming container dimensions, stowage, and biomechanical properties. Performance under weightlessness will be included as a basic phased effort of man-machine interface.

10.2.1.4.3 Equipment and Facilities. The food and water interface test program will use the facilities shown in Figure 10-4. Specific requirements include the following:

1. Human engineering development testing will be conducted in mock-ups 2 and 18. Prototype spacecraft articles will be interfaced in house spacecraft 1 (B-14).

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*VENDOR QUAL TESTS: STRENGTH, WATE
SHRINKAGE, FLEXIBILITY, FLAMMABILITY
O_2 TOXICITY, IDENTIFICATION OF GAS
CORROSION RESISTANCE, MICROBIOLO
STERILIZATION PROPERTIES (FUNGI AND

*S&ID WILL CONDUCT THE TESTS THAT THE VENDORS CANNOT PERFORM

FOOD AND WATER PROVISIONS TESTS

- LABORATORY TESTS:
  - FOOD,
  - PACKAGE SET, FOOD;
  - MOUTHPIECE, FOOD;
  - DELIVERY ASSEMBLY,
  - WATER,
  - SHELF ASSEMBLY,
  - NOOK/FOOD PREP COMPARTMENT,
  - DOOR ASSEMBLY,
  - NOOK/FOOD SHELF
  - MATERIALS TESTS: FABRICS, RUBBER, PLASTICS FINISHES, COATINGS, SURFACE TREATMENTS, SYNTHETICS, ETC
  - COMPONENTS AND SUBASSEMBLY TESTS:
  - ASSEMBLY TESTS:
  - NUTRITIONAL LABORATORY TESTS: CARBOHYDRATE, FAT, PROTEIN; VITAMINS, PRESERVATIVES, ETC
- HUMAN ENGINEERING TESTS:
  - FOOD PREPARATION TECHNIQUES,
  - FOOD AND WATER CONTAINER SIZE
  - FOOD AND WATER STORAGE,
  - CONTAINER BIOMECHANICS,
  - MENUS
  - FOOD PALATABILITY,
  - FOOD AND WATER QUANTITY
  - MOCK-UP TESTS: DEVELOPMENTAL
  - HOUSE SPACECRAFT TESTS: DEVELOPMENTAL
  - ECS BREADBOARD TESTS
  - AFRM TEST: QUALIFICATION
- CREW PERFORMANCE TESTS
- SYSTEMS COMPATIBILITY TESTS:
  - ENERGY BALANCE,
  - PREPARATION EQUIPMENT,
  - GASTROINTESTINAL HOMEOSTASIS,
  - WASTE PRODUCTS MANAGEMENT,
  - ATMOSPHERIC CONTAMINATION
  - O-g FLIGHT TESTS: PREPARATION, INGESTION, ETC
  - SYSTEMS DEVELOPMENT TESTS (SY SERIES) STORAGE FACILITIES, BIOMECHANICS, FOOD PREPARATION ◉
  - CREW INTEGRATION TESTS: FOOD PREPARATION, NUTRITION, FOOD MANAGEMENT, ETC ◉

○ TOTAL NO. OF TESTS NOTED IN CIRCLE

◉ TESTS TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENTAL SIMULATION TEST PROGRAM" (REF PARAGRAPH 10.3)

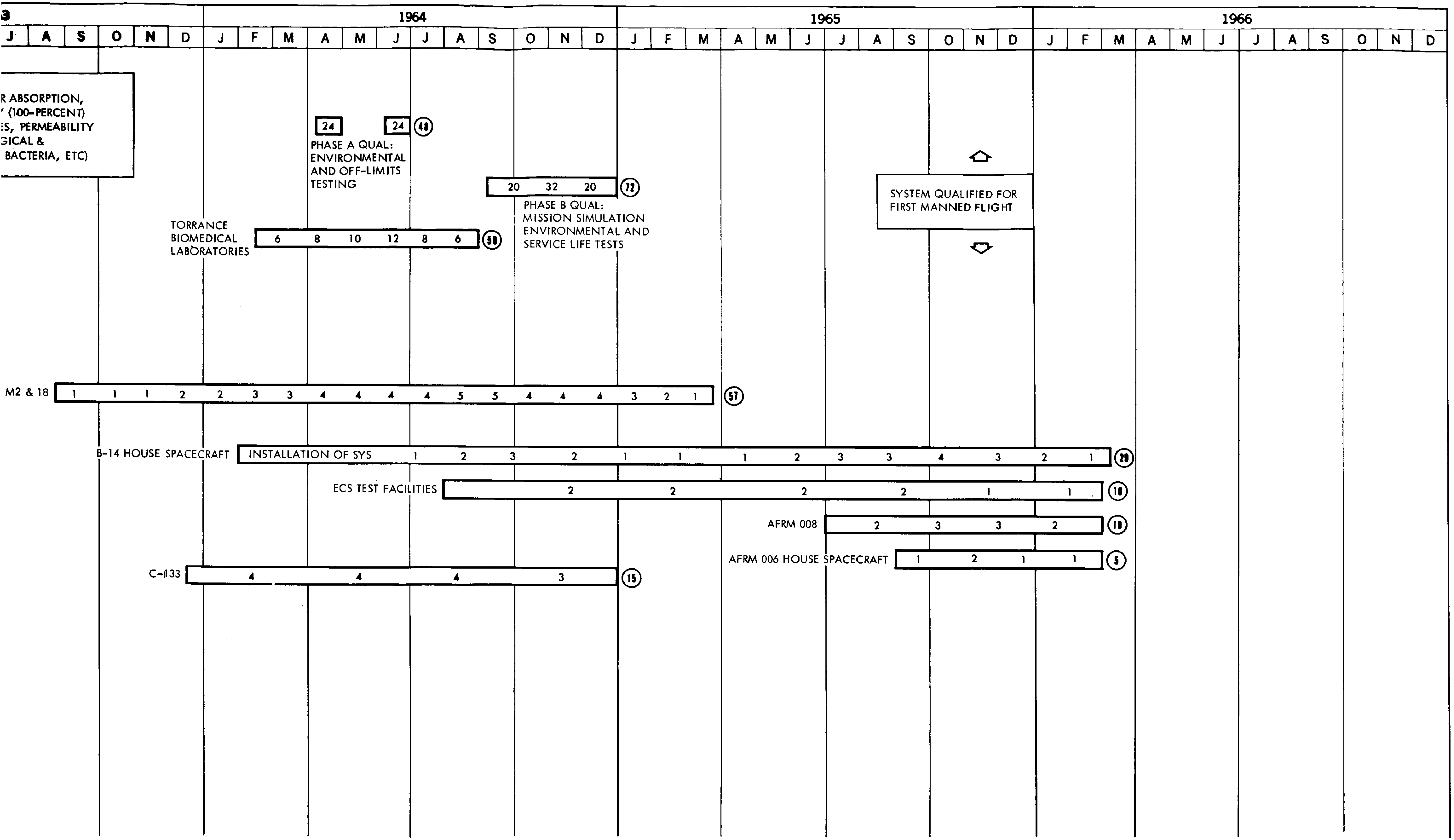

Figure 10-4. Systems Approach—Food and Water Provisions Test Program

2. Prototype hardware will use the preceding vehicles, as available, and will be terminally evaluated in Simulator 1 during the crew engineering simulation test program prior to testing of qualification items.

3. Ground verification tests will be integrated with the ECS breadboard test program.

10.2.1.4.4 Test Schedule. Food and water systems test schedules are shown in Figure 10-4. The definition of individual test dates, as equipment availability is chronologically defined, is also shown in the test schedule.

10.2.1.5 Crew Equipment and Accessories Verification Tests.

10.2.1.5.1 Objectives. Crew systems testing will verify the interface of all crew accessories equipment in conformance with Apollo design criteria reflected in SID 62-1003.

Items to be tested include the following:

1. Crew equipment

   Umbilical assembly, crewman
   Belt assembly, in-flight maintenance, crewman
   Hose assembly, charging, oxygen (PLSS, ECS)

2. Crew accessories

   Tool set, in-flight, crewman
   Egress accessories, hatch
   Light assembly, portable, crewman
   Restraint assembly, rest station, crewman
   Restraint assembly, lower equipment bay, crewman
   Sandals, weightless restraint, crewman

3. Personal hygiene equipment

   Cleaning pad set, personal
   Dentifrice ingestible, personal
   Shaver assembly, personal
   Towel assembly, utility, personal

4. Personal Communications

   Communications assembly, constant wear, personal

10.2.1.5.2 Test Requirements. Crew equipment and accessories verification tests will be conducted as follows:

10.2.1.5.2.1 Subcontractor Tests. The supplier shall have or will establish a program that conforms to the requirements of MQ 0802-001 for quality control. S&ID reserves the right to conduct engineering, reliability, quality control, and other surveys as may be deemed necessary to evaluate adequately the capabilities of the suppliers. Subcontractor tests to be performed shall be classified as development, qualification, and acceptance tests.

1. Development Tests. The supplier shall perform adequate tests during development to determine that the materials and design approach are compatible with the requirements of the procurement specification. The development tests shall be specified by the supplier and will be subject to the approval of S&ID.

2. Qualification Tests. Qualification tests shall be conducted to verify that the design and performance requirements of the procurement specification have been met. The tests shall be performed on items produced with the same tooling and processes and under the same conditions as those intended for quantity production. Qualification criteria shall be those specified for ground qualification tests. (See Volume III.)

3. Acceptance Tests. Prior to delivery and as a condition of acceptance, the provisions of Volume IV, Acceptance Test Plan, shall apply.

10.2.1.5.2.2 S&ID Test Program.

1. Mock-Up Tests. Development tests using mock-ups and breadboard test articles in mock-ups 2 and 18 will be conducted to evaluate design concepts and crew systems interfaces, e.g., stowage provisions, crew accessibility, etc.

2. Systems Integration Tests. Verification of interfaces with supporting command module systems, such as storage facilities, mechanical and electrical interfaces, environmental control system, etc., will be accomplished concurrently and in support of the house spacecraft (B-14) test program.

   The design capability of crew equipment and accessories for flight crew utilization will be evaluated during extended duration tests as part of the task analysis walk-through test program (paragraph 10.2.2) and will be integrated with the ECS breadboard manned test program (Section 5). Zero-G tests will be conducted to evaluate design compatibility with the weightless environment.

3. System Qualification Tests. Crew equipment and accessories design and man-machine interfaces will be qualified concurrently with, and as part of, the Airframe 006 vibration proof and house spacecraft program, and in conjunction with the Airframe 008 manned environmental proof test program.

10.2.1.5.3 Equipment and Facilities. The crew accessories test program will use test articles and facilities shown in Figure 10-5.

10.2.1.5.4 Test Schedule. The test schedule for crew equipment and accessories is shown in Figure 10-5.

10.2.1.6 Survival Equipment Interface Tests

10.2.1.6.1 Objectives. Tests will be conducted to verify the packaging and installation interfaces of all survival equipment items within the command module. The operational suitability of survival equipment items will be evaluated and qualified for optimum human utilization and conformance with the Apollo survival mission constraints. Collective kit GFE items to be tested include the following:

Signal mirror, survival, crewman
Sunglasses, survival, crewman
Water and container, survival, crewman
First-aid kit, survival, crewman

[redacted]

Life vest, survival, crewman
Balloon kite, survival, crewman
Life raft, one man, survival, crewman
Knife, survival, crewman
Desalting kit, survival, crewman
Transceiver, communications, survival, crewman
Light assembly, survival, crewman
Light assembly, locator, C/M

10.2.1.6.2 Test Requirements. Survival equipment tests will be conducted as follows:

10.2.1.6.2.1 Associate Contractor Tests. Development tests for survival equipment will be conducted by the NASA associate contractor as directed by the NASA. Crew Systems will monitor major test milestones and will coordinate those tests that reflect interface with the Apollo vehicle.

10.2.1.6.2.2 S&ID Systems Integration Tests.

1. Storage provisions will be functionally verified for requirements of the Apollo mission (e.g., sizing, security of attachment, access, etc.). These tests will be integrated with the Boilerplate 14 and Airframe 006 house spacecraft test programs.

2. The mobility of crewmen under all conditions of egress, including survival provisions, will be evaluated. Time-motion picture coverage and time histories for all nominal and emergency egress conditions with survival gear will be obtained for analysis and record. These tests will use the engineering mock-ups 2 and 18 and Boilerplate 1 and 2 flotation facilities.

10.2.1.6.2.3 Survival Performance Tests. Crew equipment and components will be verified for functional use in actual and simulated survival environments. A rigorous NASA test program will be conducted to test survival performance.

10.2.1.6.3 Equipment and Facilities. The survival equipment interface test program will use test articles and facilities as shown in Figure 10-6. Specific requirements are as follows:

1. Developmental and systems interface tests will use equipment mock-ups and breadboards installed in engineering mock-ups 2 and 18.

2. Systems integration of survival equipment will use developmental or first-run equipment articles installed in the house spacecraft Boilerplate 14 and Airframe 006.

3. Survival performance tests (developmental and qualification) will be conducted utilizing the Boilerplate 29 and Airframe 007

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DEVELOPMEN
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CREW EQUIPMENT AND ACCESSORIES TEST PROGRAM

CREW ACCESSORIES
- FLIGHT KIT ASSEMBLY
- TOOL SET, IN-FLIGHT
- EGRESS ACCESSORIES
- HATCH
- LIGHT ASSEMBLY-PORTABLE

CREW EQUIPMENT
- UMBILICAL ASSEMBLY
- BELT ASSEMBLY-
- INFLIGHT MAINTENANCE
- HOSE ASSEMBLY-(PLSS, ECS)
- OXYGEN CHARGING
- REDUCER-OXYGEN
- RECHARGING HOSE ASSEMBLY

PERSONAL HYGIENE EQUIPMENT
- CLEANSING PAD SET
- SHAVER ASSEMBLY
- TOWEL ASSEMBLY
- INGESTIBLE DENTRIFICE SET

PERSONAL COMMUNICATION
- COMMUNICATION ASSY. CONSTANT WEAR

LABORATORY & ENVIRONMENTAL TESTS
- MATERIALS TESTS:
  FABRICS, RUBBERS, PLASTICS FINISHES, COATINGS, SURFACE TREATMENTS, SYNTHETICS, ETC
- COMPONENTS AND SUBASSEMBLY TESTS:
  ALL ITEMS NOT QUALIFIED PER DETAILED SPECIFICATIONS AND APOLLO REQUIREMENTS
- ASSEMBLY TESTS

HUMAN ENGINEERING TESTS

ANTHROPOMETRICS, SYSTEM COMPATIBILITY, COMFORT, MOBILITY, STOWAGE PROVISIONS, ATTACHMENT, ADJUSTMENTS, BIOMECHANICS BIOLOGICAL, COMPATIBILITY

- MOCK-UP TESTS: (DEVELOPMENTAL)
- HOUSE SPACECRAFT TESTS:
  (DEVELOPMENTAL) INTERMITTENT AS AVAILABLE
- AFRM TESTS:
  LOGBOOK, TOOLS, MAINTENANCE (QUALIFICATION)
  SUPPORT EQUIPMENT
- O-G FLIGHTS:
  STOWAGE PROVISIONS, COMPATIBILITY OF PERSONAL HYGIENE EQUIPMENT, ETC

INTEGRATED DYNAMIC TESTS
- IMPACT DROP TESTS: (DEVELOPMENTAL)
  STOWAGE MOUNTING, ETC
- AFRM QUALIFICATION CENTRIFUGE TESTS: (DEVELOPMENTAL)
  (INTERMITTENT) UMBILICAL HOSE, VALVES, STOWAGE, COMFORT, EQUIPMENT EVALUATION
- VIBRATION: DEVELOPMENTAL TEST FIXTURE
- ECS BREADBOARD TESTS
- QUALIFICATION AFRM FLIGHT TESTS: (DATA ANALYSIS)

CREW PERFORMANCE TESTS
- SYSTEMS DEVELOPMENT TESTS:
  PERSONAL EQUIPMENT EVALUATION
  TESTS ASSOCIATED WITH FLIGHT SIMULATION
- CREW INTEGRATION TESTS:
  TASK-EQUIPMENT INTEGRATION
  (FLIGHT SIMULATION)

○ TOTAL NO. OF TESTS NOTED IN CIRCLE

◉ TESTS TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENTAL SIMULATION TEST PROGRAM"

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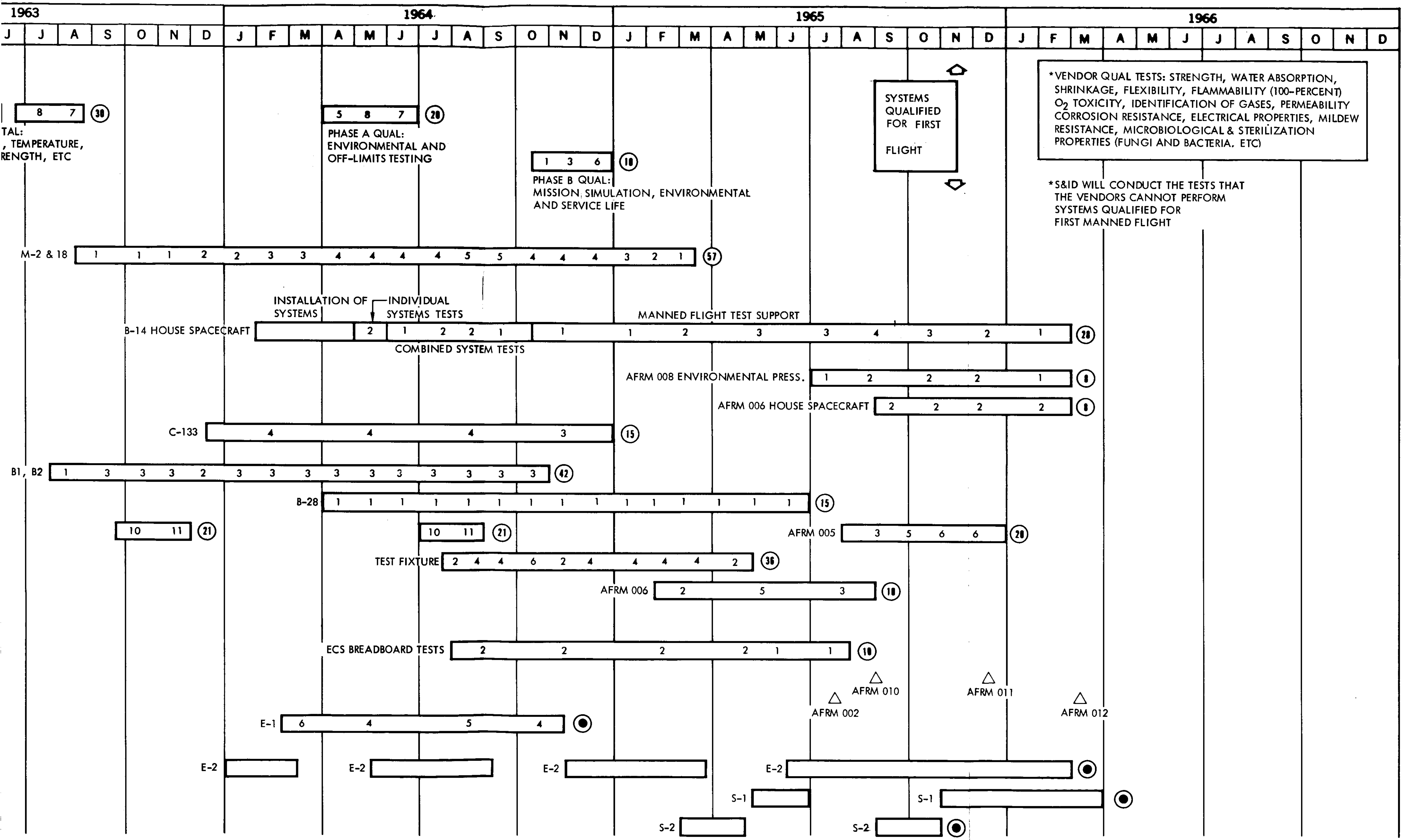


Figure 10-5. Systems Approach—Crew Equipment and Accessories Test Program

test vehicles for water egress and flotation tests. Service survival test facilities will be used, if required.

4. Human test subjects fitted with operational pressure garment assemblies will be required.

5. Time-motion photographic instrumentation will be required.

10.2.1.6.4 Test Schedule. Survival equipment tests will be scheduled within the framework shown in Figure 10-6.

10.2.1.7 Biomedical Equipment and Provisions Interface Tests

10.2.1.7.1 Objectives. First-aid equipment and biomedical provisions must be verified against Apollo design criteria and the permissible environmental range for the command module. Interfaces between physiological instrumentation and spacecraft electronic systems must be achieved. First-aid supplies will be tested for performance-degrading pharmacological changes and possible additions to the cabin debris or aerosol containment loads in a joint S&ID-NASA effort. Items to be tested include the following:

Medical kit, emergency (GFE)
Instrument set, clinical monitoring, physiological (GFE)
Instrument assembly, biomedical sensors, personal (GFE)
Instrument assembly, biomedical preamplifier (GFE)
Dosimeters, radiation, personal (GFE)

10.2.1.7.2 Test Requirements. Biomedical equipment and provisions tests will be conducted as follows:

10.2.1.7.2.1 Associate Contractor Tests. Developmental tests for biomedical equipment and provisions will be conducted by the NASA associate contractor as directed by the NASA. Crew Systems will monitor major milestones and will coordinate those tests that reflect interface with the Apollo vehicle.

10.2.1.7.2.2 Human Engineering (Apollo Integration). First-aid equipment, biomedical instrumentation, and NASA-furnished biosensors will be interfaced with the command module internal arrangement during Boilerplate 14 house spacecraft tests. Evaluation of ECS interfaces will be integrated with the manned phase of the ECS breadboard tests. Additional evaluation will continue during simulation tests in simulator 1 with final ground qualification occurring during Airframe 006 and 008 tests.

10.2.1.7.2.3 Functional Performance Tests. Biomedical and first-aid items are NASA furnished.

10.2.1.7.2.4 Biomedical Integration. The following parameters will be included as pertinent to the bioinstrumentation evaluation:

1. Verification of compatibility with other spacecraft electronic systems and GSE during prelaunch. This includes signal clarity, clinical correlation, and absence of intersystem interference.

2. Ease of attachment, removal, and response under the range of Apollo environments. The portion of bioinstrumentation dealing with the transmission of physiological instrumentation data is a communications responsibility and will be monitored by Crew Systems only as it is concerned with intelligibility at the ground monitoring receiver.

10.2.1.7.3 Equipment and Facilities. The biomedical integration program is reflected in Figure 10-7. Specific requirements include the following:

1. Apollo integration testing will use evaluator 2, Boilerplate 14, and the centrifuge program. It will be concurrent with human engineering evaluations and biomedical functional tests integrated with the ECS breadboard tests and will require both human subjects and appropriate pressure garment assemblies (the latter due to a necessary interface with the crew clothing subsystem).

2. Appropriate data bits will be recorded and retained for biomedical evaluation and correlation with standard clinical information and will result in the establishment of baseline information for use during manned flight.

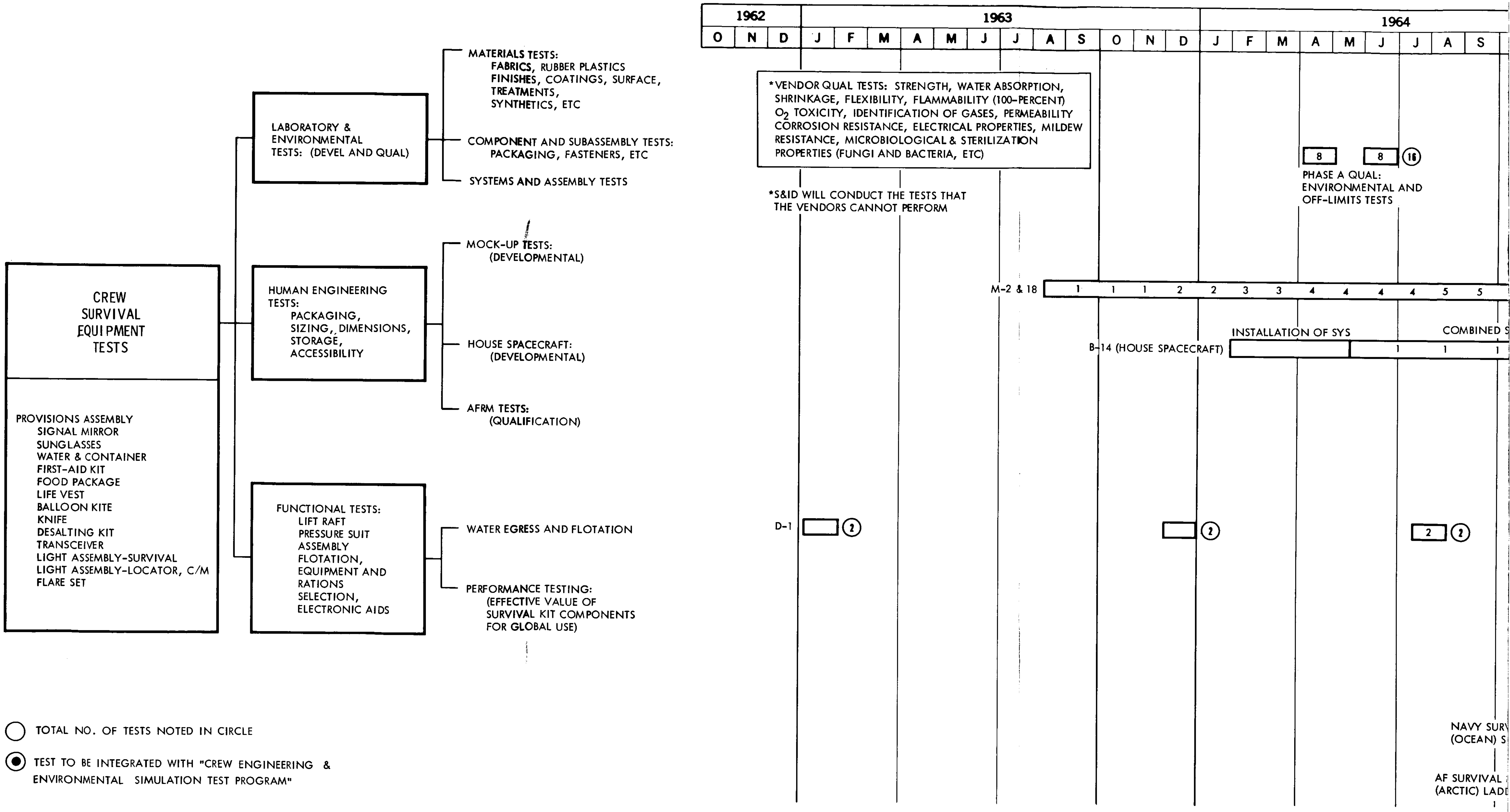
10.2.1.7.4 Test Schedule. The test schedule for first-aid and biomedical equipment tests is shown in Figure 10-7.

10.2.2 Spacecraft (Crew) Systems Interface Tests

A comprehensive test program will evaluate the human engineering interfaces of the flight crew with systems and equipment installed in the command module. The crew systems human engineering test program presently includes the following:

Control-display system interfaces
Command module interior interfaces
Illumination systems
Waste management system interfaces
Environmental control system interfaces
GSE (checkout, auxiliary servicing, and handling) systems

[redacted]


CREW SURVIVAL EQUIPMENT TESTS
PROVISIONS ASSEMBLY
SIGNAL MIRROR
SUNGLASSES
WATER & CONTAINER
FIRST-AID KIT
FOOD PACKAGE
LIFE VEST
BALLOON KITE
KNIFE
DESALTING KIT
TRANSCEIVER
LIGHT ASSEMBLY-SURVIVAL
LIGHT ASSEMBLY-LOCATOR, C/M
FLARE SET
LABORATORY & ENVIRONMENTAL TESTS: (DEVEL AND QUAL)
MATERIALS TESTS: FABRICS, RUBBER PLASTICS FINISHES, COATINGS, SURFACE, TREATMENTS, SYNTHETICS, ETC
COMPONENT AND SUBASSEMBLY TESTS: PACKAGING, FASTENERS, ETC
SYSTEMS AND ASSEMBLY TESTS
HUMAN ENGINEERING TESTS: PACKAGING, SIZING, DIMENSIONS, STORAGE, ACCESSIBILITY
MOCK-UP TESTS: (DEVELOPMENTAL)
HOUSE SPACECRAFT: (DEVELOPMENTAL)
AFRM TESTS: (QUALIFICATION)
FUNCTIONAL TESTS: LIFT RAFT PRESSURE SUIT ASSEMBLY FLOTATION, EQUIPMENT AND RATIONS SELECTION, ELECTRONIC AIDS
WATER EGRESS AND FLOTATION
PERFORMANCE TESTING: (EFFECTIVE VALUE OF SURVIVAL KIT COMPONENTS FOR GLOBAL USE)
1962
1963
1964
O N D J F M A M J J A S O N D J F M A M J J A S
*VENDOR QUAL TESTS: STRENGTH, WATER ABSORPTION, SHRINKAGE, FLEXIBILITY, FLAMMABILITY (100-PERCENT) O2 TOXICITY, IDENTIFICATION OF GASES, PERMEABILITY CORROSION RESISTANCE, ELECTRICAL PROPERTIES, MILDEW RESISTANCE, MICROBIOLOGICAL & STERILIZATION PROPERTIES (FUNGI AND BACTERIA, ETC)
*S&ID WILL CONDUCT THE TESTS THAT THE VENDORS CANNOT PERFORM
8
8
16
PHASE A QUAL: ENVIRONMENTAL AND OFF-LIMITS TESTS
M-2 & 18
1 1 1 2 2 3 3 4 4 4 4 5 5
INSTALLATION OF SYS
COMBINED S
B-14 (HOUSE SPACECRAFT)
1 1 1
D-1
2
2
2
2
NAVY SURV (OCEAN) S
AF SURVIVAL (ARCTIC) LADD
TOTAL NO. OF TESTS NOTED IN CIRCLE
TEST TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENTAL SIMULATION TEST PROGRAM"

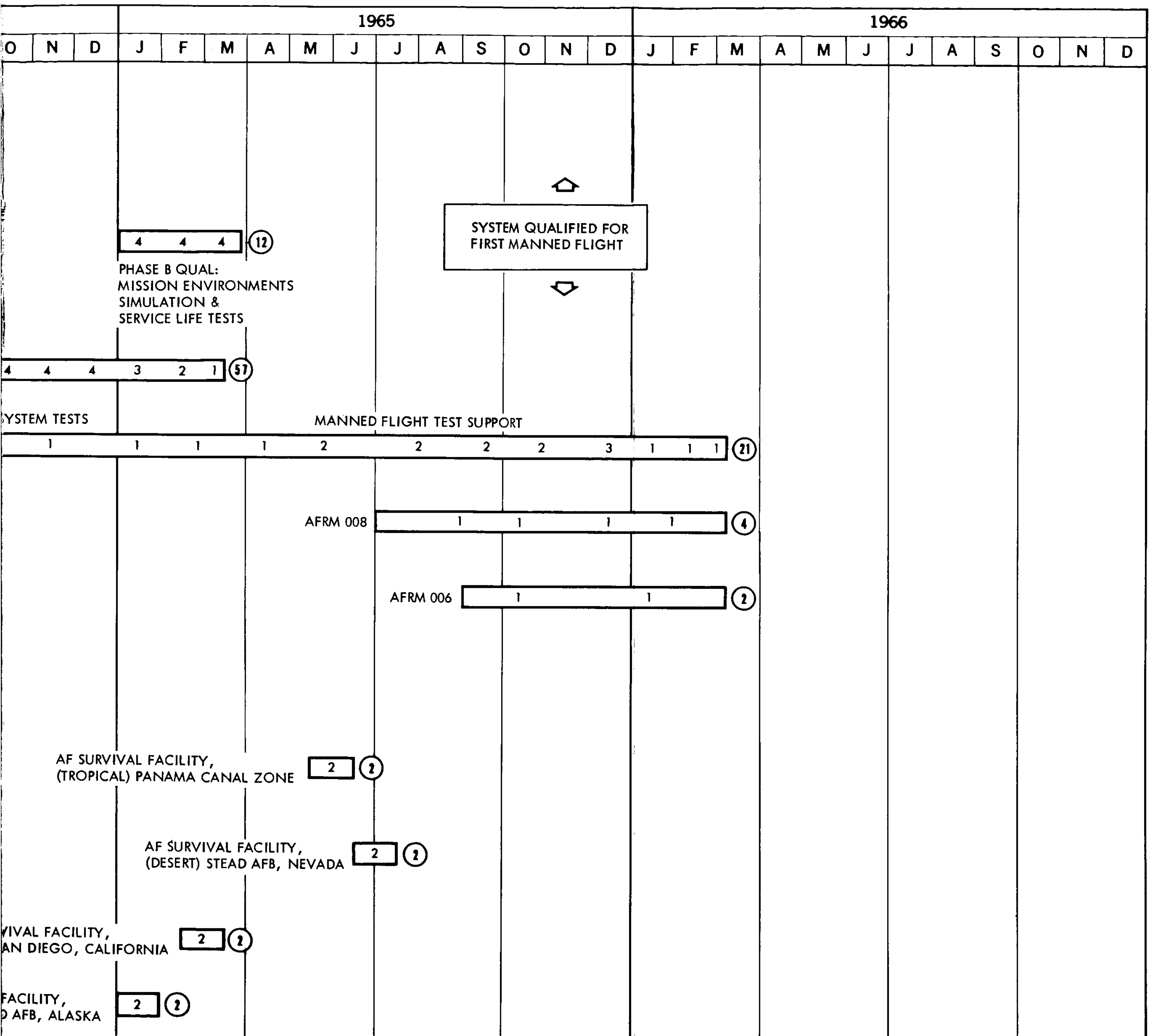
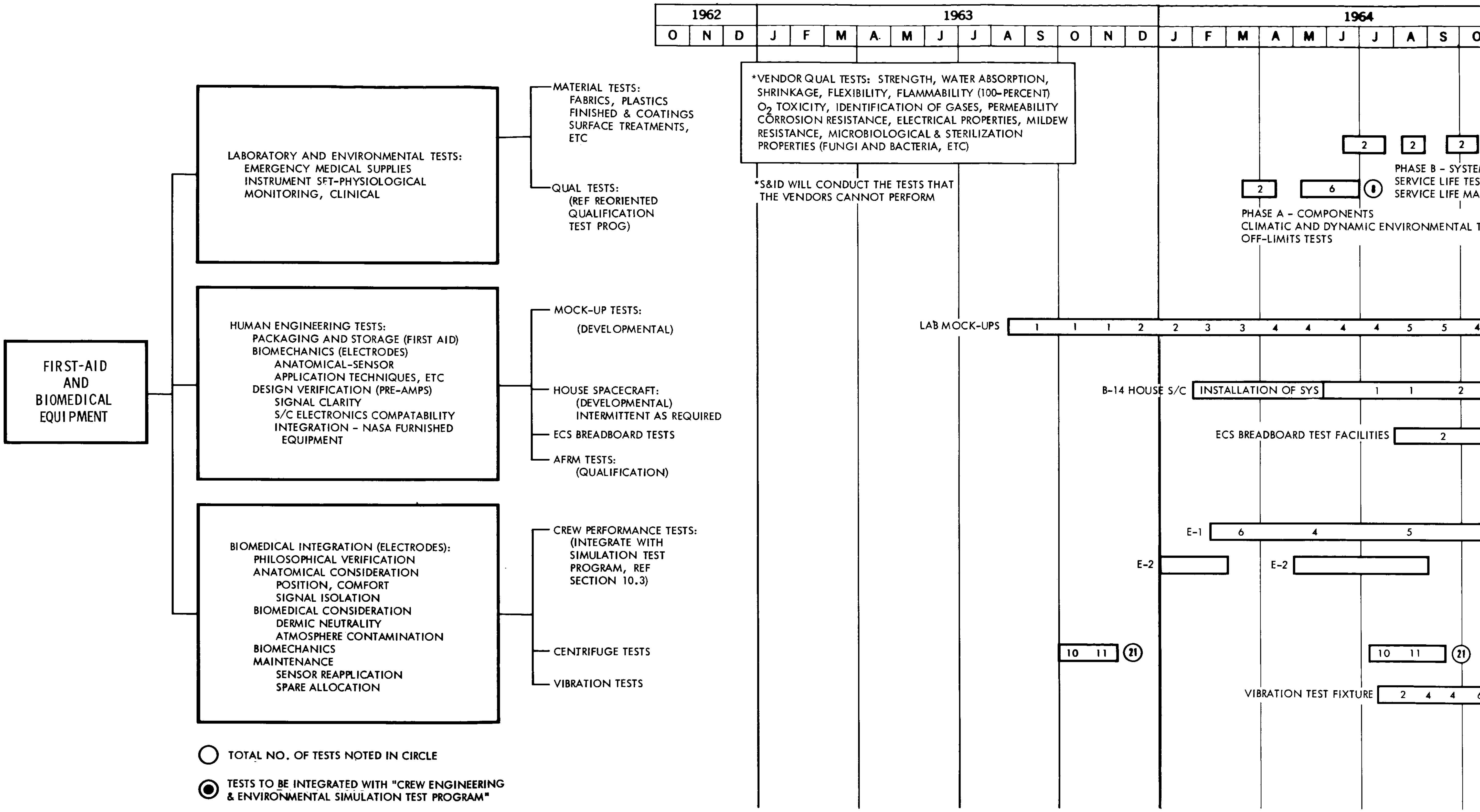


Figure 10-6. Systems Approach—Crew Survival Equipment Test Program

[redacted]


1962
1963
1964
O N D J F M A M J J A S O N D J F M A M J J A S O
FIRST-AID AND BIOMEDICAL EQUIPMENT
LABORATORY AND ENVIRONMENTAL TESTS:
EMERGENCY MEDICAL SUPPLIES
INSTRUMENT SET-PHYSIOLOGICAL
MONITORING, CLINICAL
MATERIAL TESTS:
FABRICS, PLASTICS
FINISHED & COATINGS
SURFACE TREATMENTS,
ETC
QUAL TESTS:
(REF REORIENTED
QUALIFICATION
TEST PROG)
*VENDOR QUAL TESTS: STRENGTH, WATER ABSORPTION, SHRINKAGE, FLEXIBILITY, FLAMMABILITY (100-PERCENT) O2 TOXICITY, IDENTIFICATION OF GASES, PERMEABILITY CORROSION RESISTANCE, ELECTRICAL PROPERTIES, MILDEW RESISTANCE, MICROBIOLOGICAL & STERILIZATION PROPERTIES (FUNGI AND BACTERIA, ETC)
*S&ID WILL CONDUCT THE TESTS THAT THE VENDORS CANNOT PERFORM
PHASE B - SYSTEM
SERVICE LIFE TES
SERVICE LIFE MA
PHASE A - COMPONENTS
CLIMATIC AND DYNAMIC ENVIRONMENTAL T
OFF-LIMITS TESTS
HUMAN ENGINEERING TESTS:
PACKAGING AND STORAGE (FIRST AID)
BIOMECHANICS (ELECTRODES)
ANATOMICAL-SENSOR
APPLICATION TECHNIQUES, ETC
DESIGN VERIFICATION (PRE-AMPS)
SIGNAL CLARITY
S/C ELECTRONICS COMPATABILITY
INTEGRATION - NASA FURNISHED
EQUIPMENT
MOCK-UP TESTS:
(DEVELOPMENTAL)
LAB MOCK-UPS
HOUSE SPACECRAFT:
(DEVELOPMENTAL)
INTERMITTENT AS REQUIRED
B-14 HOUSE S/C
INSTALLATION OF SYS
ECS BREADBOARD TESTS
ECS BREADBOARD TEST FACILITIES
AFRM TESTS:
(QUALIFICATION)
BIOMEDICAL INTEGRATION (ELECTRODES):
PHILOSOPHICAL VERIFICATION
ANATOMICAL CONSIDERATION
POSITION, COMFORT
SIGNAL ISOLATION
BIOMEDICAL CONSIDERATION
DERMIC NEUTRALITY
ATMOSPHERE CONTAMINATION
BIOMECHANICS
MAINTENANCE
SENSOR REAPPLICATION
SPARE ALLOCATION
CREW PERFORMANCE TESTS:
(INTEGRATE WITH
SIMULATION TEST
PROGRAM, REF
SECTION 10.3)
E-1
E-2
E-2
CENTRIFUGE TESTS
VIBRATION TESTS
VIBRATION TEST FIXTURE
TOTAL NO. OF TESTS NOTED IN CIRCLE
TESTS TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENTAL SIMULATION TEST PROGRAM"

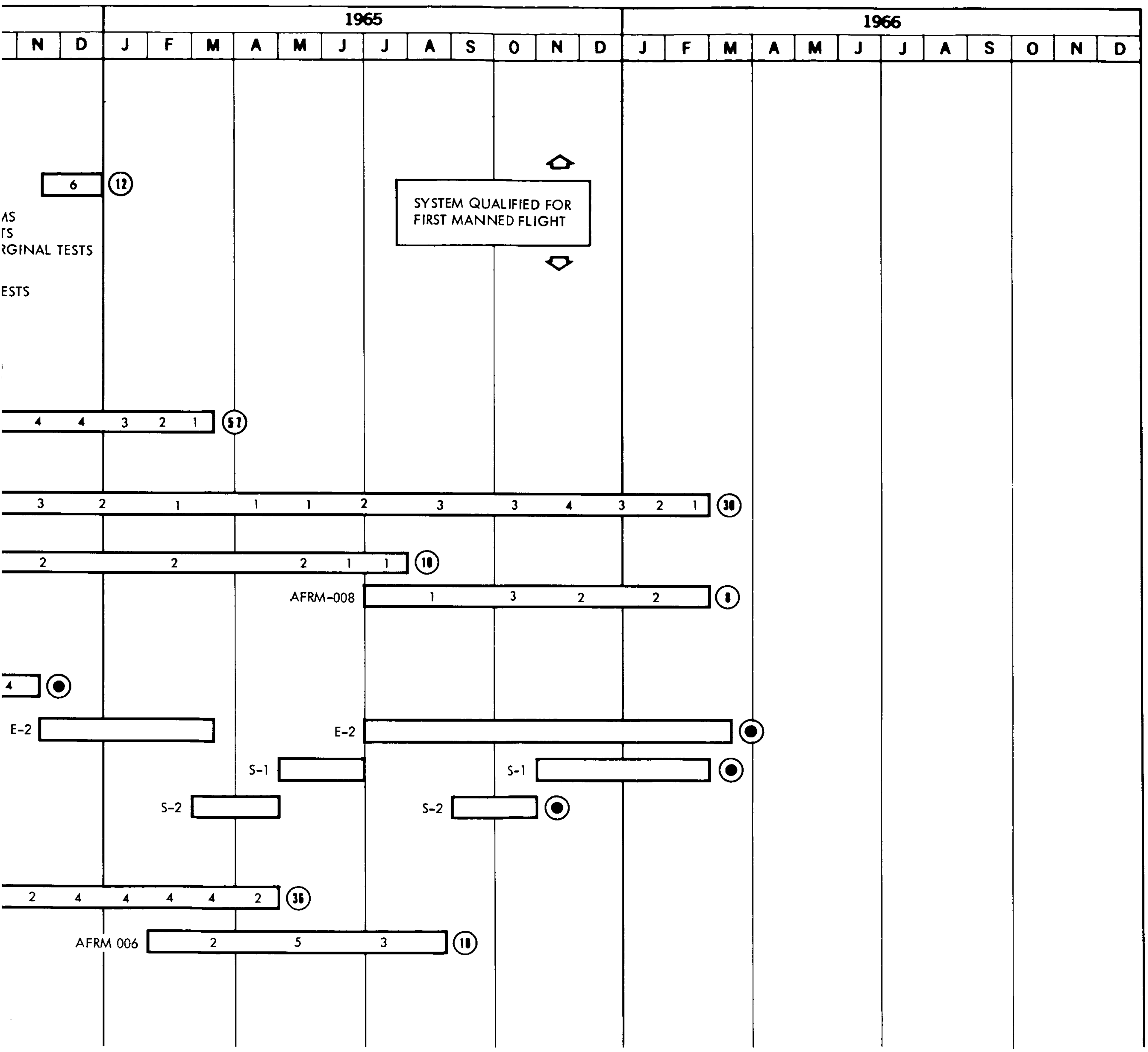


Figure 10-7. Systems Approach—First-Aid and Biomedical Equipment Test Program

Human engineering test requirements for the above equipment systems are defined in the following paragraphs.

10.2.2.1 Control-Display System Interface Tests

10.2.2.1.1 Test Requirements.

10.2.2.1.1.1 Component Evaluation. The design and selection of individual control-display components will be verified for conformance with S&ID and NASA human engineering criteria and specifications.

10.2.2.1.1.2 Systems Evaluation. Evaluation of design and configurational layout of primary and secondary control-display systems for conformance with system functions criteria will be made. Functions analyses and task and time-line analyses of critical systems will be conducted to verify optimum layout of primary and secondary control-display systems.

10.2.2.1.1.3 Integrated Systems Evaluation. Design and configuration of integrated control-display systems will be verified for conformance with crew function and crew task allocation criteria. Crew task and crew functions analyses will be prepared, and link and time-line analyses will assure optimum configuration of integrated control-display systems.

10.2.2.1.1.4 Preliminary Task Analysis Evaluation. The flight crew task analysis will be evaluated in static mock-ups. These mock-up walk-through studies will be conducted for both the preliminary and final task analyses (flight crew performance specifications) for each manned flight. The task analysis will be evaluated with respect to task sequential flow, compatibility with display-control configuration, gross operational times, and visual and reach envelopes. Suited and unsuited conditions will be studied.

10.2.2.1.1.5 Design for Maintainability (Ground and In-Flight). Maintainability design will be evaluated for conformance with ground and in-flight maintainability criteria. Human engineering analyses and simulated malfunction and alignment tests will determine the extent of maintenance, tool, and equipment requirements.

10.2.2.1.2 Equipment and Facilities. The control-display system test program will use test articles and facilities as shown in Figure 10-8. Specific requirements are as follows:

1. Design developmental tests will use equipment mock-ups and breadboards installed in engineering mock-ups 2 and 18.

[redacted]

2. Systems evaluation and integrated systems evaluation will use developmental or first-run hardware installed in the house spacecraft Boilerplate 14 or Airframe 006.

3. Functional performance will be evaluated and qualified during the crew engineering and environmental simulation test program (see paragraph 10. 3).

4. Human subjects fitted with operational pressure garment assemblies will be required.

10. 2. 2. 1. 3 Test Schedule. The control-display test program will be scheduled within the developmental framework shown in Figure 10-8.

10. 2. 2. 2 Command Module Interior Interface Tests

10. 2. 2. 2. 1 Test Requirements.

10. 2. 2. 2. 1. 1 Command Module Interior Configuration. Verification of design and configuration of individual crew stations, primary and secondary duty stations, and rest and relief stations for conformance with Apollo crew systems design criteria will be sought. Fit-check evaluation tests with human subjects (10 through 90 percentile) and other tests will verify interior design conformance with human anatomical limitations. Seating, functional reach, visual envelopes, and crew mobility will be evaluated.

1. Crew Station Functional Arrangement. Design and configuration of crew station arrangements will be verified for over-all conformance with crew task and operations criteria. Crew task evaluations and simulated operational missions will be conducted to evaluate equipment accessibility and general cabin arrangements.

2. Storage Facilities and Attachment Fixtures. Design of storage facilities and attachment fixtures will be verified for compatibility with all nonstructural crew equipment (e. g., pressure suit storage, scientific equipment storage, tool kits, spares, etc.). Dimensions and configurations and size and shape of storage and attachment fixtures for the various equipment items in the cabin interior will be evaluated.

3. Maintainability Design (Ground and In-Flight). Over-all design and configuration of in-flight test provisions will be evaluated for conformance with S&ID and NASA in-flight maintainability criteria.

[redacted]

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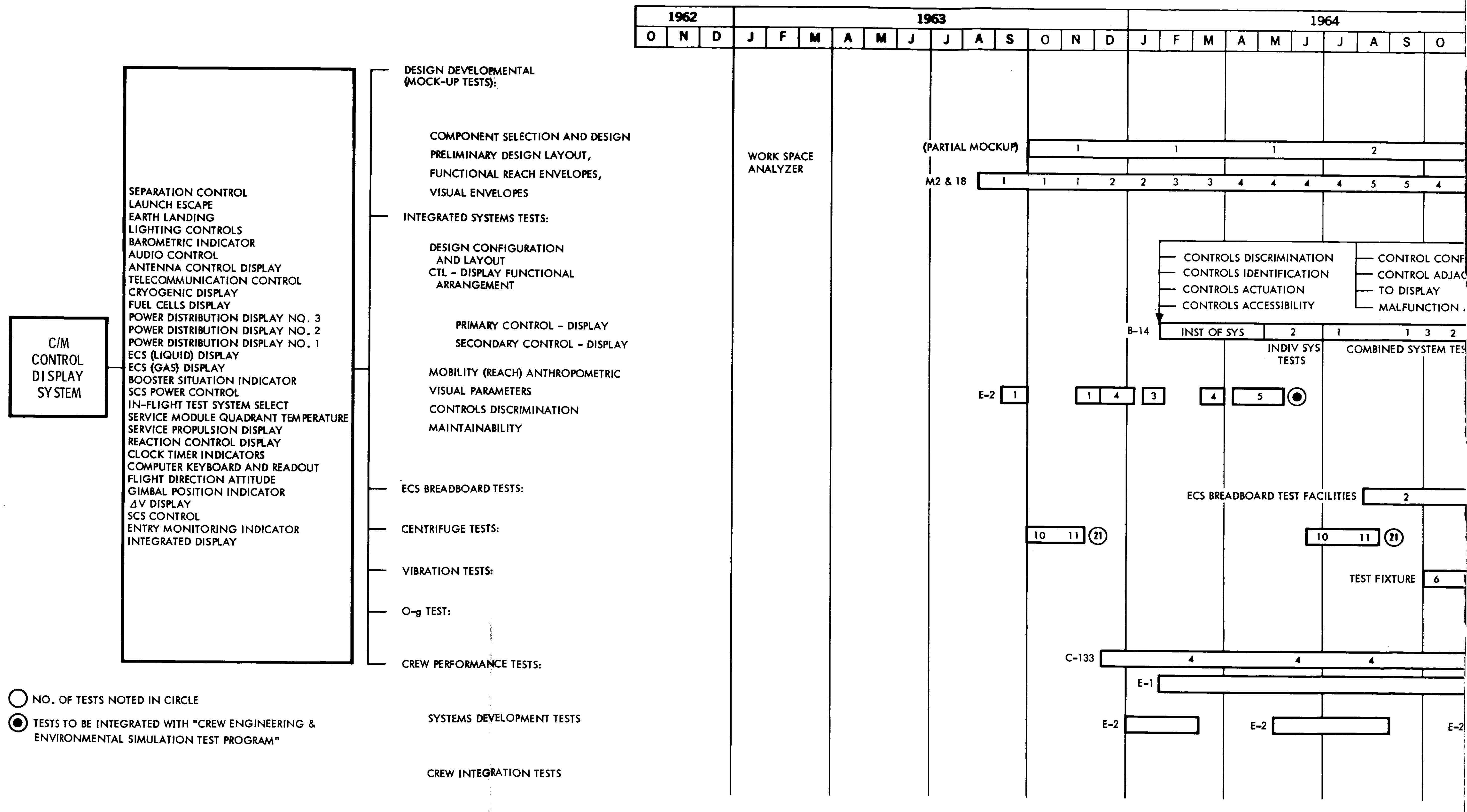

1962
1963
1964
O N D J F M A M J J A S O N D J F M A M J J A S O
C/M CONTROL DISPLAY SYSTEM
SEPARATION CONTROL
LAUNCH ESCAPE
EARTH LANDING
LIGHTING CONTROLS
BAROMETRIC INDICATOR
AUDIO CONTROL
ANTENNA CONTROL DISPLAY
TELECOMMUNICATION CONTROL
CRYOGENIC DISPLAY
FUEL CELLS DISPLAY
POWER DISTRIBUTION DISPLAY NO. 3
POWER DISTRIBUTION DISPLAY NO. 2
POWER DISTRIBUTION DISPLAY NO. 1
ECS (LIQUID) DISPLAY
ECS (GAS) DISPLAY
BOOSTER SITUATION INDICATOR
SCS POWER CONTROL
IN-FLIGHT TEST SYSTEM SELECT
SERVICE MODULE QUADRANT TEMPERATURE
SERVICE PROPULSION DISPLAY
REACTION CONTROL DISPLAY
CLOCK TIMER INDICATORS
COMPUTER KEYBOARD AND READOUT
FLIGHT DIRECTION ATTITUDE
GIMBAL POSITION INDICATOR
ΔV DISPLAY
SCS CONTROL
ENTRY MONITORING INDICATOR
INTEGRATED DISPLAY
DESIGN DEVELOPMENTAL (MOCK-UP TESTS):
COMPONENT SELECTION AND DESIGN
PRELIMINARY DESIGN LAYOUT,
FUNCTIONAL REACH ENVELOPES,
VISUAL ENVELOPES
INTEGRATED SYSTEMS TESTS:
DESIGN CONFIGURATION AND LAYOUT
CTL - DISPLAY FUNCTIONAL ARRANGEMENT
PRIMARY CONTROL - DISPLAY
SECONDARY CONTROL - DISPLAY
MOBILITY (REACH) ANTHROPOMETRIC
VISUAL PARAMETERS
CONTROLS DISCRIMINATION
MAINTAINABILITY
ECS BREADBOARD TESTS:
CENTRIFUGE TESTS:
VIBRATION TESTS:
O-g TEST:
CREW PERFORMANCE TESTS:
SYSTEMS DEVELOPMENT TESTS
CREW INTEGRATION TESTS
WORK SPACE ANALYZER
(PARTIAL MOCKUP)
M2 & 18
CONTROLS DISCRIMINATION
CONTROLS IDENTIFICATION
CONTROLS ACTUATION
CONTROLS ACCESSIBILITY
B-14
INST OF SYS
INDIV SYS TESTS
COMBINED SYSTEM TES
E-2
ECS BREADBOARD TEST FACILITIES
TEST FIXTURE
C-133
E-1
NO. OF TESTS NOTED IN CIRCLE
TESTS TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENTAL SIMULATION TEST PROGRAM"

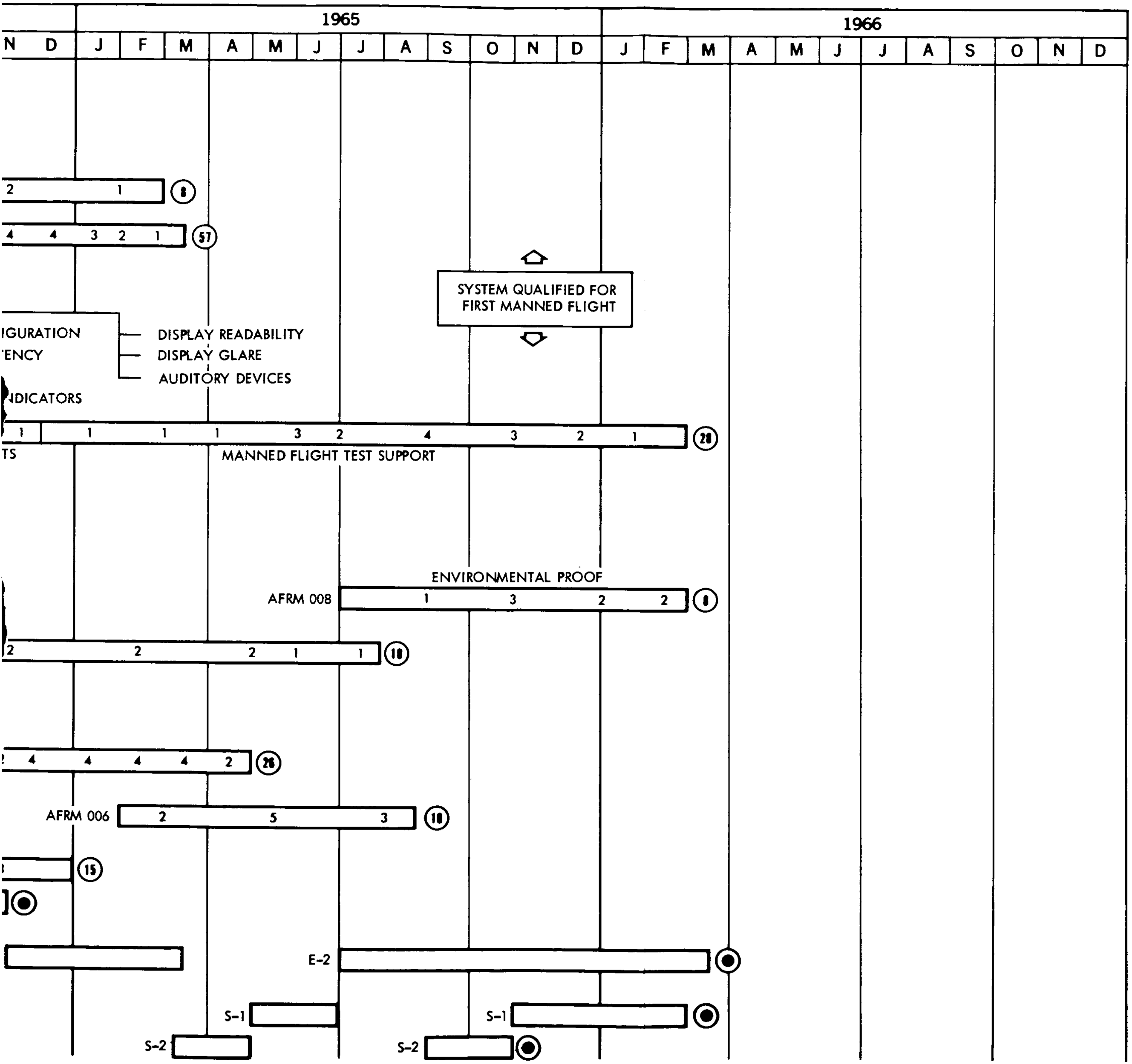

Figure 10-8. Systems Approach—Command Module Control-Display Systems Human Engineering Test Program

[redacted]

Simulated malfunction tests will be conducted to determine the extent of maintenance requirements, tools, and equipment required.

10.2.2.2.1.2 Command Module Interior Color Evaluation.

1. Cabin Interior Components. Performance tests will be conducted to evaluate visual comfort and controls discrimination. These tests are described in paragraph 10.2.2.3.

10.2.2.2.1.3 Windows and Shutters.

1. Design Evaluation. Window design will be evaluated for conformance with S&ID and NASA human engineering design criteria. Tests will be conducted to evaluate the field of view provided by the windows and shutters as related to the various couch adjustments and positions. Test requirements to verify crew protection from heat and high-intensity illumination transients will be coordinated, as required.

2. Optical Design Evaluation. Laboratory evaluation tests will be conducted, as required, to assess the optical qualities of the windows and verify the provisions and interactions for use with cameras, periscope, telescopes, and sextant optical devices.

10.2.2.2.1.4 Docking Egress Provisions.

1. Human Engineering Design Verification. The docking transit tunnel and hatch design and configuration will be evaluated for conformance with S&ID and NASA crew system design criteria. The dimensions of the transit tunnel will be verified for anthropometric compatibility. The operation of the system will be functionally verified, and tests will be conducted to evaluate ground and in-flight maintainability provisions.

2. Ingress and Egress Tests. Tests will functionally evaluate the design provisions for crew ingress-egress during all Apollo mission phases (ground and in-space, nominal and emergency, and under zero-G conditions). These tests will be conducted with human subjects (10 through 90 percentile) equipped with pressurized suits and the portable life support system. Tests will be performed under zero-G conditions and in altitude chambers to provide realistic environmental conditions. Underwater tests will be performed to evaluate emergency egress during submerged conditions.

[redacted]

10.2.2.2.1.5 Access Hatches.

1. Human Engineering Design Verification Tests. The crew access hatch will be evaluated for design and configuration conformance with S&ID and NASA crew system design criteria. Tests will be conducted to evaluate the hatch dimensions, configuration and location for compatibility with crew anthropometrics, and location and operational requirements to ensure optimum crew utilization. Operation of the system will be functionally evaluated, and the provisions for ground and in-flight maintenance will be tested.

2. Ingress and Egress. Tests will be conducted with human subjects (10 through 90 percentile) to evaluate the hatch and related systems for optimum crew ingress-egress provisions. These tests will be implemented with mock-up tests and will include simulated land, water, nominal, and emergency egress conditions. Underwater tests will evaluate emergency egress, if submerged.

10.2.2.2.2 Equipment and Facilities. Cabin arrangement tests will use test articles and facilities as shown in Figure 10-9. Specific requirements are as follows:

1. Design developmental tests will use equipment mock-ups and breadboard articles installed in the engineering mock-ups 2 and 18.

2. Human engineering tests will use developmental or first-run hardware installed in the house spacecraft Boilerplate 14 or Airframe 006.

3. Functional performance tests will be conducted during the crew engineering and environmental simulation test program (see paragraph 10.3).

4. Dynamic qualification tests will be performed as part of the environmental proof test program (see Volume V, Multiple Systems Tests). Zero-G tests will require utilization of the USAF C-135 zero-G laboratory.

5. Human test subjects fitted with operation pressure suits will be required.

10.2.2.2.3 Test Schedule. The cabin arrangement test program will be scheduled within the developmental framework shown in Figure 10-9.

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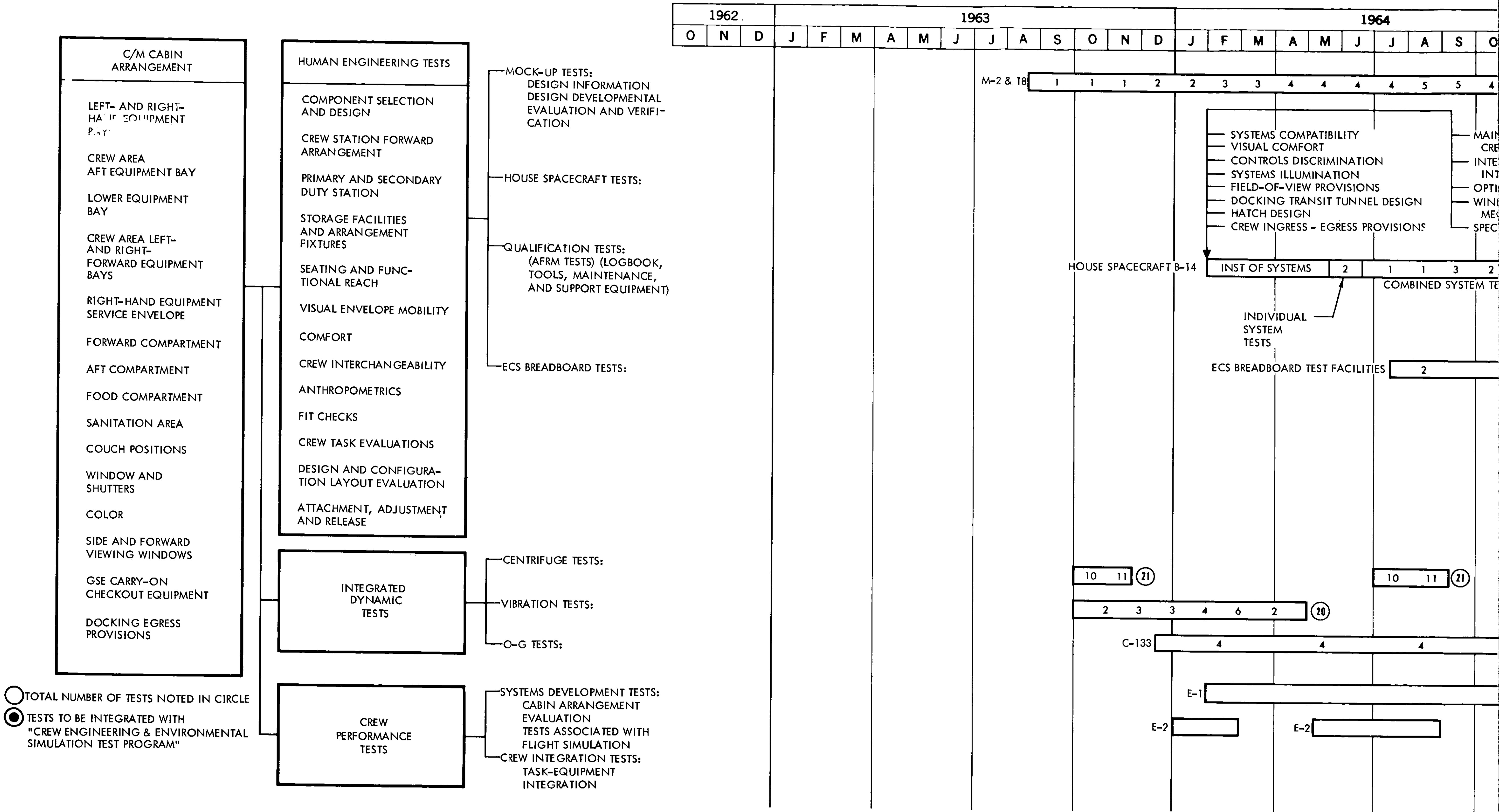

C/M CABIN ARRANGEMENT
LEFT- AND RIGHT-HAND EQUIPMENT BAYS
CREW AREA AFT EQUIPMENT BAY
LOWER EQUIPMENT BAY
CREW AREA LEFT- AND RIGHT- FORWARD EQUIPMENT BAYS
RIGHT-HAND EQUIPMENT SERVICE ENVELOPE
FORWARD COMPARTMENT
AFT COMPARTMENT
FOOD COMPARTMENT
SANITATION AREA
COUCH POSITIONS
WINDOW AND SHUTTERS
COLOR
SIDE AND FORWARD VIEWING WINDOWS
GSE CARRY-ON CHECKOUT EQUIPMENT
DOCKING EGRESS PROVISIONS
TOTAL NUMBER OF TESTS NOTED IN CIRCLE
TESTS TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENTAL SIMULATION TEST PROGRAM"
HUMAN ENGINEERING TESTS
COMPONENT SELECTION AND DESIGN
CREW STATION FORWARD ARRANGEMENT
PRIMARY AND SECONDARY DUTY STATION
STORAGE FACILITIES AND ARRANGEMENT FIXTURES
SEATING AND FUNCTIONAL REACH
VISUAL ENVELOPE MOBILITY
COMFORT
CREW INTERCHANGEABILITY
ANTHROPOMETRICS
FIT CHECKS
CREW TASK EVALUATIONS
DESIGN AND CONFIGURATION LAYOUT EVALUATION
ATTACHMENT, ADJUSTMENT AND RELEASE
INTEGRATED DYNAMIC TESTS
CREW PERFORMANCE TESTS
MOCK-UP TESTS: DESIGN INFORMATION DESIGN DEVELOPMENTAL EVALUATION AND VERIFICATION
HOUSE SPACECRAFT TESTS:
QUALIFICATION TESTS: (AFRM TESTS) (LOGBOOK, TOOLS, MAINTENANCE, AND SUPPORT EQUIPMENT)
ECS BREADBOARD TESTS:
CENTRIFUGE TESTS:
VIBRATION TESTS:
O-G TESTS:
SYSTEMS DEVELOPMENT TESTS: CABIN ARRANGEMENT EVALUATION TESTS ASSOCIATED WITH FLIGHT SIMULATION
CREW INTEGRATION TESTS: TASK-EQUIPMENT INTEGRATION
1962
O N D
1963
J F M A M J J A S O N D
1964
J F M A M J J A S O
M-2 & 18
1 1 1 2 2 3 3 4 4 4 4 5 5 4
SYSTEMS COMPATIBILITY
VISUAL COMFORT
CONTROLS DISCRIMINATION
SYSTEMS ILLUMINATION
FIELD-OF-VIEW PROVISIONS
DOCKING TRANSIT TUNNEL DESIGN
HATCH DESIGN
CREW INGRESS - EGRESS PROVISIONS
HOUSE SPACECRAFT B-14
INST OF SYSTEMS
2 1 1 3 2
COMBINED SYSTEM TE
INDIVIDUAL SYSTEM TESTS
ECS BREADBOARD TEST FACILITIES
2
10 11 (21)
10 11 (21)
2 3 3 4 6 2 (20)
C-133
4 4 4
E-1
E-2
E-2

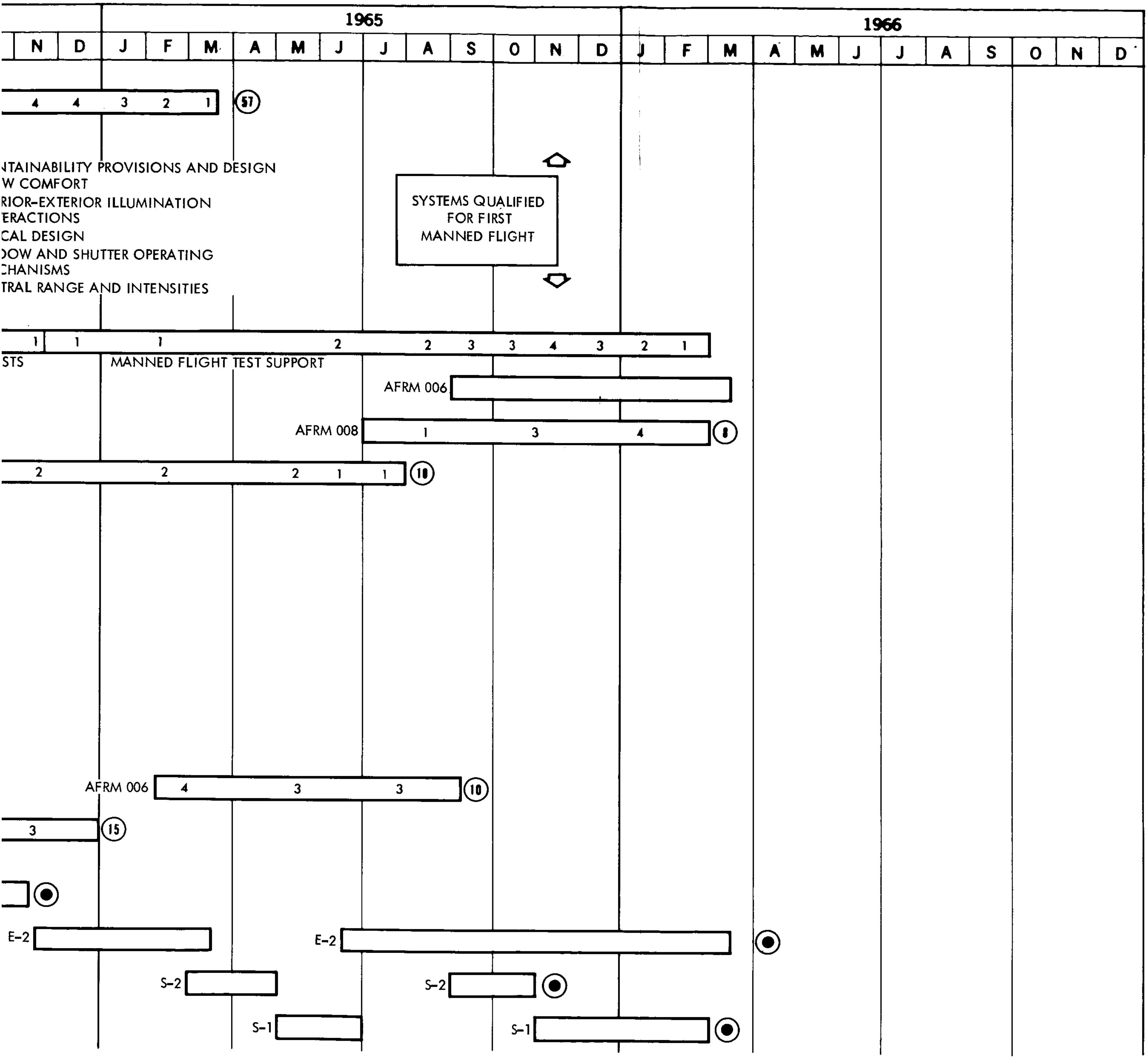

Figure 10-9. Systems Approach—Command Module Interior Configuration Test Program

[redacted]

10.2.2.3 Illumination Systems Evaluation

10.2.2.3.1 <u>Test Requirements.</u>

10.2.2.3.1.1 Subjective Evaluation. Testing will be accomplished to assure an adequate visual environment as outlined in specifications and requirements established by S&ID Crew Systems and NASA for crew operations. Operations and instructions will be verified using various means of illumination, light control devices, and display presentations in conjunction with a simulated background of appropriate space ambient luminary sources. Controlled subject performance tests will also evaluate optical illusions, parallax, visual comfort and fatigue, reflections, and tolerance to predicted visual intensities.

10.2.2.3.1.2 Objective Evaluation.

1. Tests will be conducted to assess illumination systems operation and interaction, color, contrasts, display presentation clarity, lighting control location and actuation, fixture design and placement, brightness levels, filter operation, emergency provisions, color of light, intensity levels, reflection, glare, and lamp distribution as pertinent to the over-all spacecraft environment.

2. EDL illumination equipment and control device testing will be monitored in order to confirm the following:

   a. Photometric brightness of illumination produced by equipment

   b. Color of equipment and illumination by comparison or by spectrophotometric methods

   c. Contrast ratios

   d. Equipment compatibility with environmental conditions as related to man-machine interaction

   e. Glass requirements

   f. Grease and stain resistance of finishes

   g. Actions of various coatings, such as light filter assemblies, reflective and absorbing coatings

   h. Interior and exterior lighting interaction photometrically and spectrophotometrically

3. Specific systems, equipment, and materials which will undergo appraisal of the following:

   a. Interior floodlighting, consisting of arrangement of fixtures, system operation, colors, gloss, contrasts, and color of lighting

   b. Interior integral lighting, consisting of application, system operation, color of finishes and gloss, contrasts, color of lighting, and MIT equipment

   c. Effectivity and use of portable light

   d. Exterior illumination, consisting of flashing, position, and docking floodlights

   e. Emergency handle lighting (buttons)

   f. Rescue lighting aids

10.2.2.3.2 Equipment and Facilities. Subcontractor and vendor facilities will be used to the fullest extent in achieving over-all test objectives. However, where subcontractor or vendor facilities are inadequate, S&ID facilities will be used to complete qualification requirements. Representative contractor facilities which are certain to contribute to the Apollo illumination systems evaluation include the following:

1. Engineering Development Laboratory (EDL)

2. Mock-up 12, lighting and vision development

3. Boilerplate 14

4. Airframe 008

5. Miscellaneous meters, projectors, lighting equipment, photometers, and spectrophotometers (S&ID furnished)

10.2.2.3.3 Test Schedule. The sequence of testing will be scheduled within the framework illustrated in Figure 10-10.

10.2.2.4 Waste Management System Interface Tests

10.2.2.4.1 Test Requirements.

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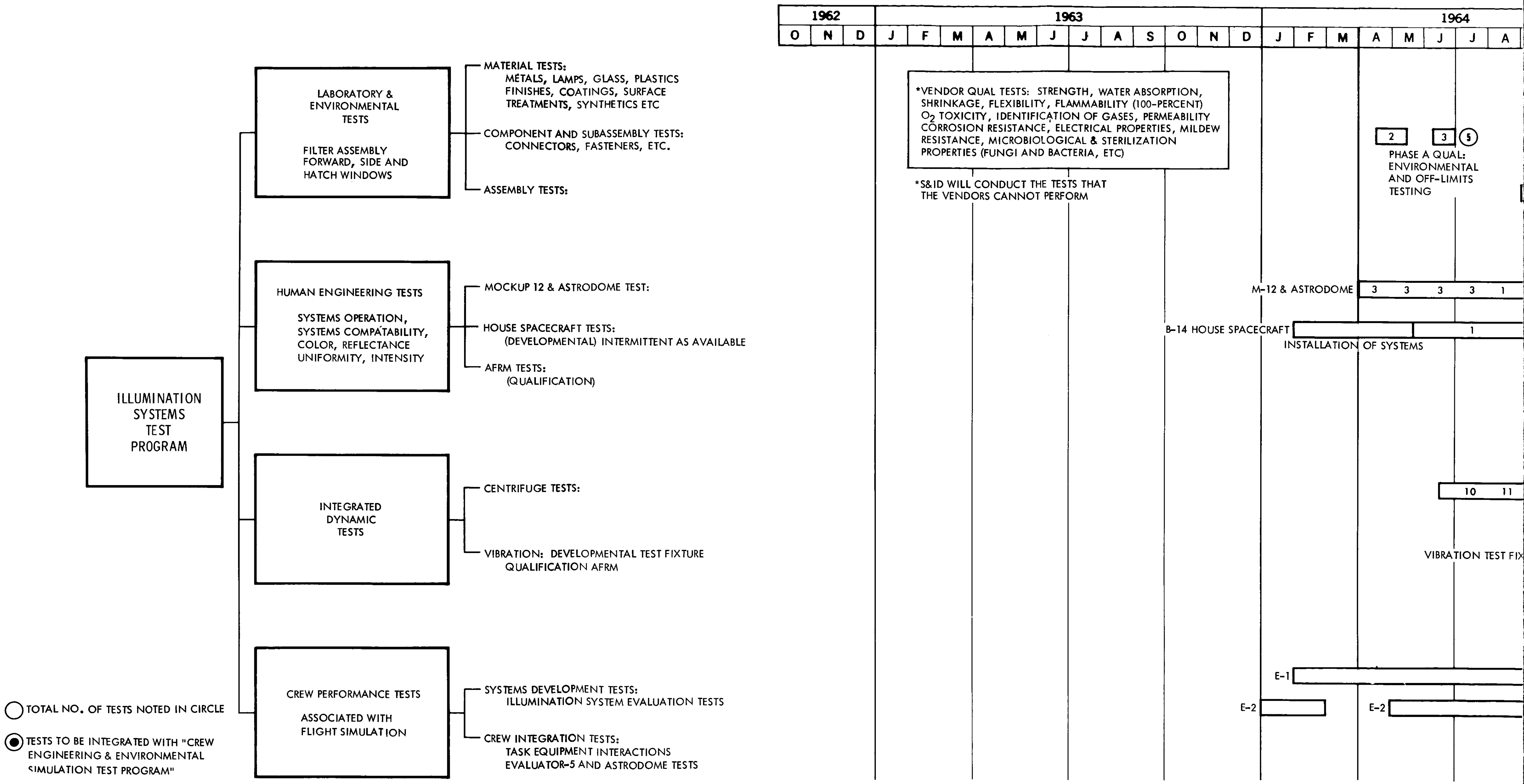

ILLUMINATION SYSTEMS TEST PROGRAM
LABORATORY & ENVIRONMENTAL TESTS
FILTER ASSEMBLY FORWARD, SIDE AND HATCH WINDOWS
MATERIAL TESTS: METALS, LAMPS, GLASS, PLASTICS FINISHES, COATINGS, SURFACE TREATMENTS, SYNTHETICS ETC
COMPONENT AND SUBASSEMBLY TESTS: CONNECTORS, FASTENERS, ETC.
ASSEMBLY TESTS:
HUMAN ENGINEERING TESTS
SYSTEMS OPERATION, SYSTEMS COMPATABILITY, COLOR, REFLECTANCE UNIFORMITY, INTENSITY
MOCKUP 12 & ASTRODOME TEST:
HOUSE SPACECRAFT TESTS: (DEVELOPMENTAL) INTERMITTENT AS AVAILABLE
AFRM TESTS: (QUALIFICATION)
INTEGRATED DYNAMIC TESTS
CENTRIFUGE TESTS:
VIBRATION: DEVELOPMENTAL TEST FIXTURE QUALIFICATION AFRM
CREW PERFORMANCE TESTS
ASSOCIATED WITH FLIGHT SIMULATION
SYSTEMS DEVELOPMENT TESTS: ILLUMINATION SYSTEM EVALUATION TESTS
CREW INTEGRATION TESTS: TASK EQUIPMENT INTERACTIONS EVALUATOR-5 AND ASTRODOME TESTS
TOTAL NO. OF TESTS NOTED IN CIRCLE
TESTS TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENTAL SIMULATION TEST PROGRAM"
1962
1963
1964
O N D J F M A M J J A S O N D J F M A M J J A
*VENDOR QUAL TESTS: STRENGTH, WATER ABSORPTION, SHRINKAGE, FLEXIBILITY, FLAMMABILITY (100-PERCENT) O_2 TOXICITY, IDENTIFICATION OF GASES, PERMEABILITY CORROSION RESISTANCE, ELECTRICAL PROPERTIES, MILDEW RESISTANCE, MICROBIOLOGICAL & STERILIZATION PROPERTIES (FUNGI AND BACTERIA, ETC)
*S&ID WILL CONDUCT THE TESTS THAT THE VENDORS CANNOT PERFORM
2
3
5
PHASE A QUAL: ENVIRONMENTAL AND OFF-LIMITS TESTING
M-12 & ASTRODOME
3 3 3 3 1
B-14 HOUSE SPACECRAFT
1
INSTALLATION OF SYSTEMS
10 11
VIBRATION TEST FIX
E-1
E-2
E-2

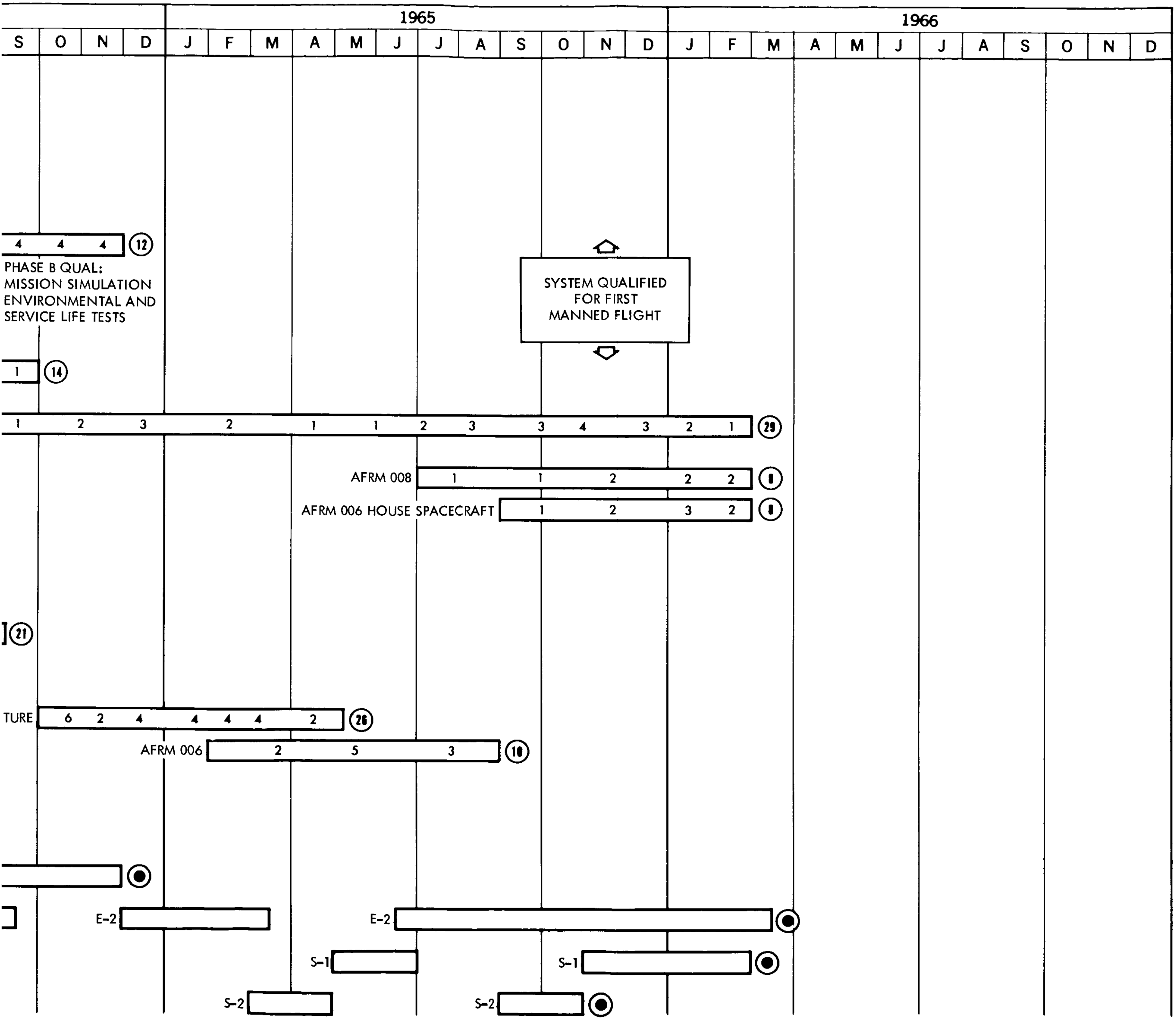

Figure 10-10. Systems Approach—Illumination Systems Test Program

[redacted]

2

10.2.2.4.1.1 Collection Device Evaluation. The design of feces, urine, and oral waste collection devices and receptacles will be evaluated for compatibility with human anatomy and lower equipment bay restraint.

10.2.2.4.1.2 Collection System Evaluation. The functional design of the feces and urine collection systems will be evaluated for conformance with Apollo crew systems design criteria. Functional tests of the collection system for human waste using human subjects during simulated Apollo missions will be conducted.

10.2.2.4.1.3 Bacteriological Control. Laboratory tests will be conducted to evaluate the bacteriological control capabilities of the management system for human waste.

10.2.2.4.2 Equipment and Facilities. The waste management system test program will use test articles and facilities shown in Figure 10-11. Specific requirements are:

1. Design developmental tests will use equipment mock-ups and breadboards installed in the engineering mock-ups 2 and 18.
2. Human engineering design evaluation tests will use developmental or first-run hardware installed in the house spacecraft B-14.
3. Performance and preliminary microbiological control tests will be conducted during the crew engineering and environmental simulation test program. (See paragraph 10.3.) (Completed)
4. Waste system functional microbiological control tests will be integrated with the ECS breadboard manned test program.
5. Qualification tests will use final design articles installed in the house spacecraft Airframe 006 and in the environmental proof spacecraft Airframe 008.
6. Human test subjects will be required.
7. Microbiological control laboratory tests will be conducted by the S&ID Life Sciences Laboratory.

10.2.2.4.3 Test Schedule. The waste management test program will be scheduled within the developmental framework shown in Figure 10-11.

10.2.2.5 Environmental Control System Interface Tests

[redacted]

10.2.2.5.1 Test Requirements.

10.2.2.5.1.1 Subcontractor Tests. Design development verification tests for the environmental control system design and function will be conducted by the subcontractor as outlined in Section 5.0, Environmental Control System. Crew Systems will be cognizant of all system level tests and monitor those which may reflect Apollo crew systems integration requirements.

10.2.2.5.1.2 Human Engineering Tests. Testing is necessary to verify design criteria and examine man-machine interfaces pertinent to atmospheric and thermal control. Validation of human input criteria to the system, including biomechanical areas, such as the CO_2 and odor canister replacement, will be accomplished on a concurrent basis with ECS control and panel evaluation. The information will be integrated with the physiological constraints defined during verification of the subcontracted system.

An associated effort will be the integration of environmental control components and personal hygiene, waste management, and nutritional subsystems. Tests described herein will be a part of the ECS breadboard tests.

10.2.2.5.1.3 Crew Systems Verification Tests. S&ID is responsible for integration of subcontractor equipment into the over-all Apollo vehicle system. A crew systems functional verification of mission compatibility will accompany such an integration and will assure compatibility with other personal support subsystems. Crew systems will furnish requirements for evaluations of crew ECS interfaces during the manned phase of the breadboard tests. Evaluations by Crew Systems during these tests will include the following:

1. Acceptability of the shirt-sleeve environment in the command module
2. Pressure suit assembly operation in the command module
3. Gas partial pressures, total pressure, and contaminant control
4. Crew metabolic and thermal balance for the Apollo mission
5. Charging provisions for the personal life support system
6. Consumption rates of atmospheric make-up gases under normal leak rate and emergency pressure loss

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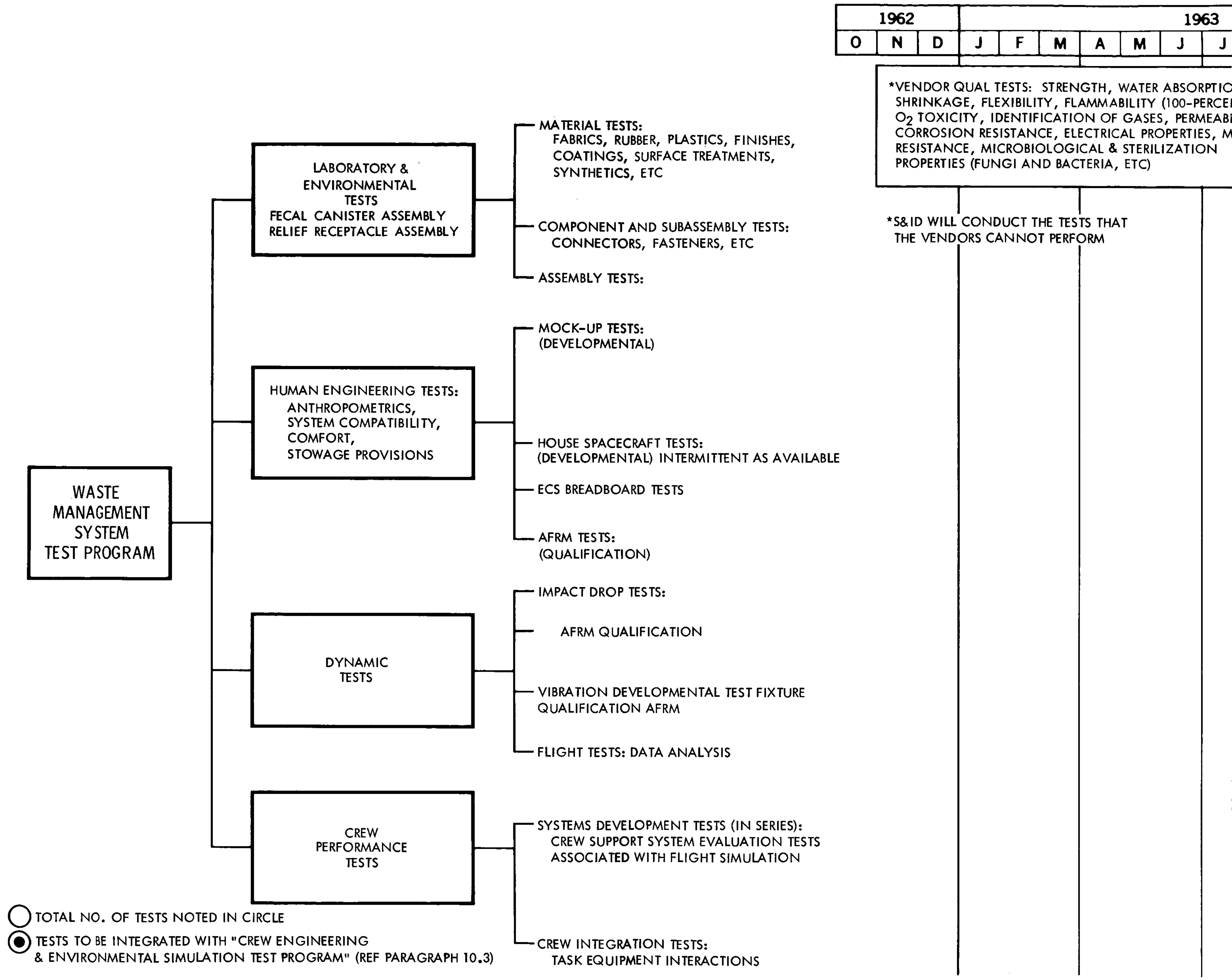
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*VENDOR QUAL TESTS: STRENGTH, WATER ABSORPTIO
SHRINKAGE, FLEXIBILITY, FLAMMABILITY (100-PERCE
O2 TOXICITY, IDENTIFICATION OF GASES, PERMEAB
CORROSION RESISTANCE, ELECTRICAL PROPERTIES, M
RESISTANCE, MICROBIOLOGICAL & STERILIZATION
PROPERTIES (FUNGI AND BACTERIA, ETC)
*S&ID WILL CONDUCT THE TESTS THAT THE VENDORS CANNOT PERFORM
WASTE MANAGEMENT SYSTEM TEST PROGRAM
LABORATORY & ENVIRONMENTAL TESTS
FECAL CANISTER ASSEMBLY
RELIEF RECEPTACLE ASSEMBLY
MATERIAL TESTS:
FABRICS, RUBBER, PLASTICS, FINISHES, COATINGS, SURFACE TREATMENTS, SYNTHETICS, ETC
COMPONENT AND SUBASSEMBLY TESTS:
CONNECTORS, FASTENERS, ETC
ASSEMBLY TESTS:
HUMAN ENGINEERING TESTS:
ANTHROPOMETRICS,
SYSTEM COMPATIBILITY,
COMFORT,
STOWAGE PROVISIONS
MOCK-UP TESTS:
(DEVELOPMENTAL)
HOUSE SPACECRAFT TESTS:
(DEVELOPMENTAL) INTERMITTENT AS AVAILABLE
ECS BREADBOARD TESTS
AFRM TESTS:
(QUALIFICATION)
DYNAMIC TESTS
IMPACT DROP TESTS:
AFRM QUALIFICATION
VIBRATION DEVELOPMENTAL TEST FIXTURE
QUALIFICATION AFRM
FLIGHT TESTS: DATA ANALYSIS
CREW PERFORMANCE TESTS
SYSTEMS DEVELOPMENT TESTS (IN SERIES):
CREW SUPPORT SYSTEM EVALUATION TESTS
ASSOCIATED WITH FLIGHT SIMULATION
CREW INTEGRATION TESTS:
TASK EQUIPMENT INTERACTIONS
TOTAL NO. OF TESTS NOTED IN CIRCLE
TESTS TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENTAL SIMULATION TEST PROGRAM" (REF PARAGRAPH 10.3)

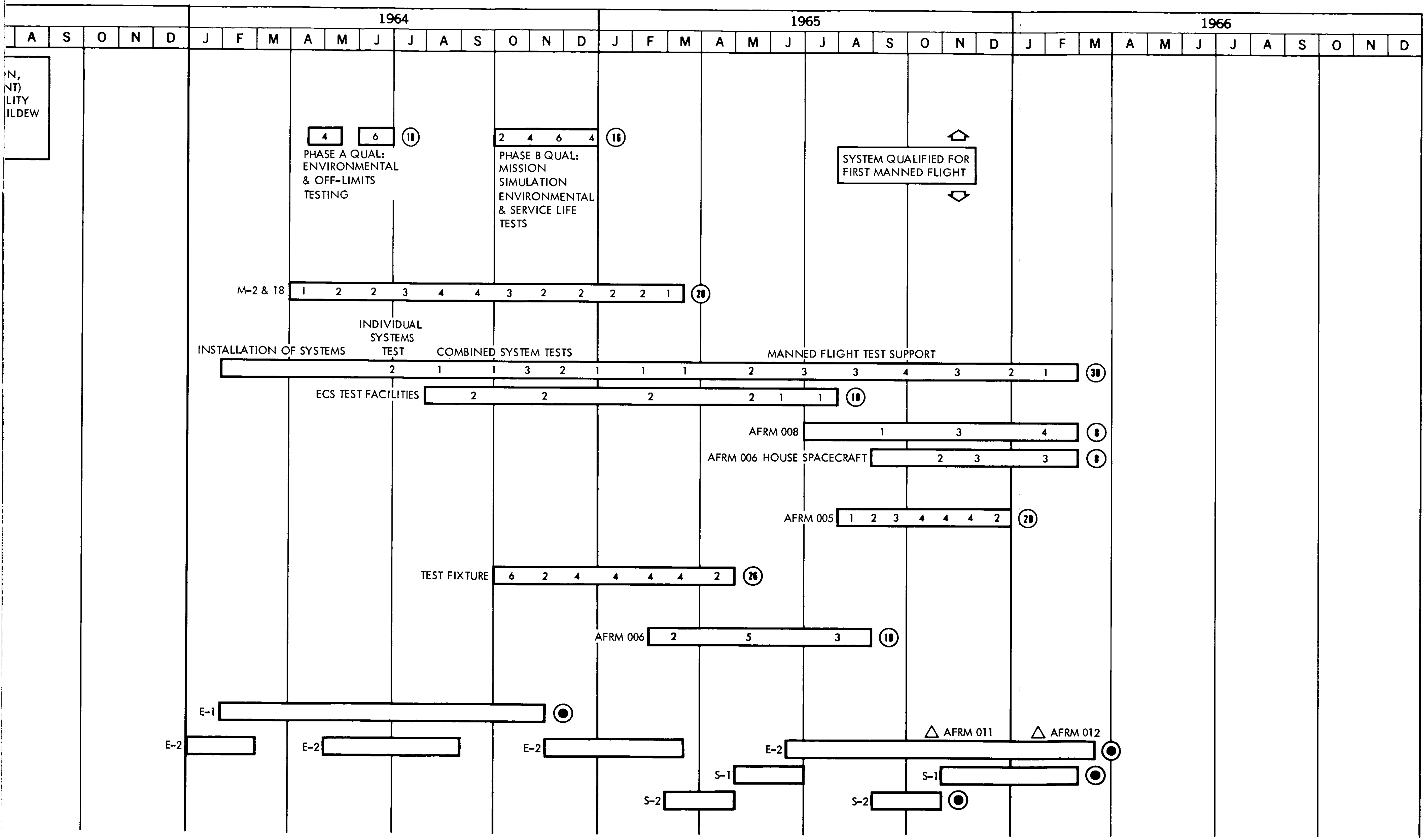

Figure 10-11. Systems Approach—Waste Management System Test Program

7. Command module air-flow distribution

8. Removal of command module particulate debris by vacuum cleaning

9. Reliability and function of pressure relief, flow limiting, and postlanding safety devices

10. In-flight maintenance and expendable absorbent replenishment

11. Flood flow post decompression

12. Repressurization from vacuum

13. Crew food and waste management systems

14. Crew equipment compatibility

10.2.2.5.2 Equipment and Facilities. S&ID conducted verification tests will use the test articles and facilities as shown in Figure 10-12.

10.2.2.5.2.1 Human Engineering Facilities. Mock-up 18 and Boilerplate 14 (house spacecraft 1) will be used to check the man-machine interface, and the system will be verified in Airframe 006 (house spacecraft 2). This program will provide the necessary feedback to the subcontractors and will assure successful mating of all life support systems at the flight test level.

10.2.2.5.2.2 Evaluation Facilities.

1. Verification of prototype display and control concepts will be conducted in mock-ups 2 and 18 in conjunction with other personal support subsystem tests. These tests will use simulated ECS components and displays and will stress man-machine functions, as related to necessary physical tasks and systems surveillance.

2. Full ECS operation, under 5-psi, 100-percent oxygen conditions, will be accomplished in the Downey man-rated space chamber using the ECS test capsule in conjunction with the ECS breadboard test program. Biophysical and biochemical functions will be assessed as a part of these studies.

3. Qualification tests using man-rated production components will be conducted in Airframe 008; they will confirm the final aspects of reliability and the achievement of an acceptable man-machine relationship.

[redacted]

4. Metabolic simulators will precede human subjects equipped with full pressure suits and will provide baseline information for follow-on toxicity and bacteriological investigations.

10.2.2.5.3 Test Schedule. The general time-test relationships are shown in Figure 10-12. Specific tests that fall within this framework include the following:

1. Human engineering mock-up tests
2. Four-hour system checkouts—ECS breadboard tests
3. Eight-hour system checkouts—ECS breadboard tests
4. Three-day and seven-day system checkouts—ECS breadboard tests
5. Fourteen-day environmental tests, one programmed—ECS breadboard tests
6. Airframe 008 thermal-vacuum tests

10.2.2.5 GSE (Checkout, Auxiliary Servicing, and Handling) Systems Tests

10.2.2.6.1 Test Requirements.

10.2.2.6.1.1 Component Evaluation. The design of GSE display components will be verified for conformance with NASA and/or S&ID human engineering specifications and recommendations.

10.2.2.6.1.2 System Evaluation. Design of GSE control-display panel interfaces will be evaluated to ensure optimum functional grouping. Performance tests (functions, task, time-line, etc.) will be conducted to verify optimum configurational layout of GSE control-display panel and console interfaces.

10.2.2.6.1.3 Integrated Systems. Integrated performance tests will be conducted to verify GSE-flight vehicle interface compatibility (equipment accessibility, ease of connections, communications, safety, etc.) to assure optimum configuration of the integrated systems.

10.2.2.6.1.4 Handling and Servicing Equipment. Tests will be conducted to evaluate human engineering compatibility of Apollo checkout and handling and servicing systems and procedures with the over-all launch

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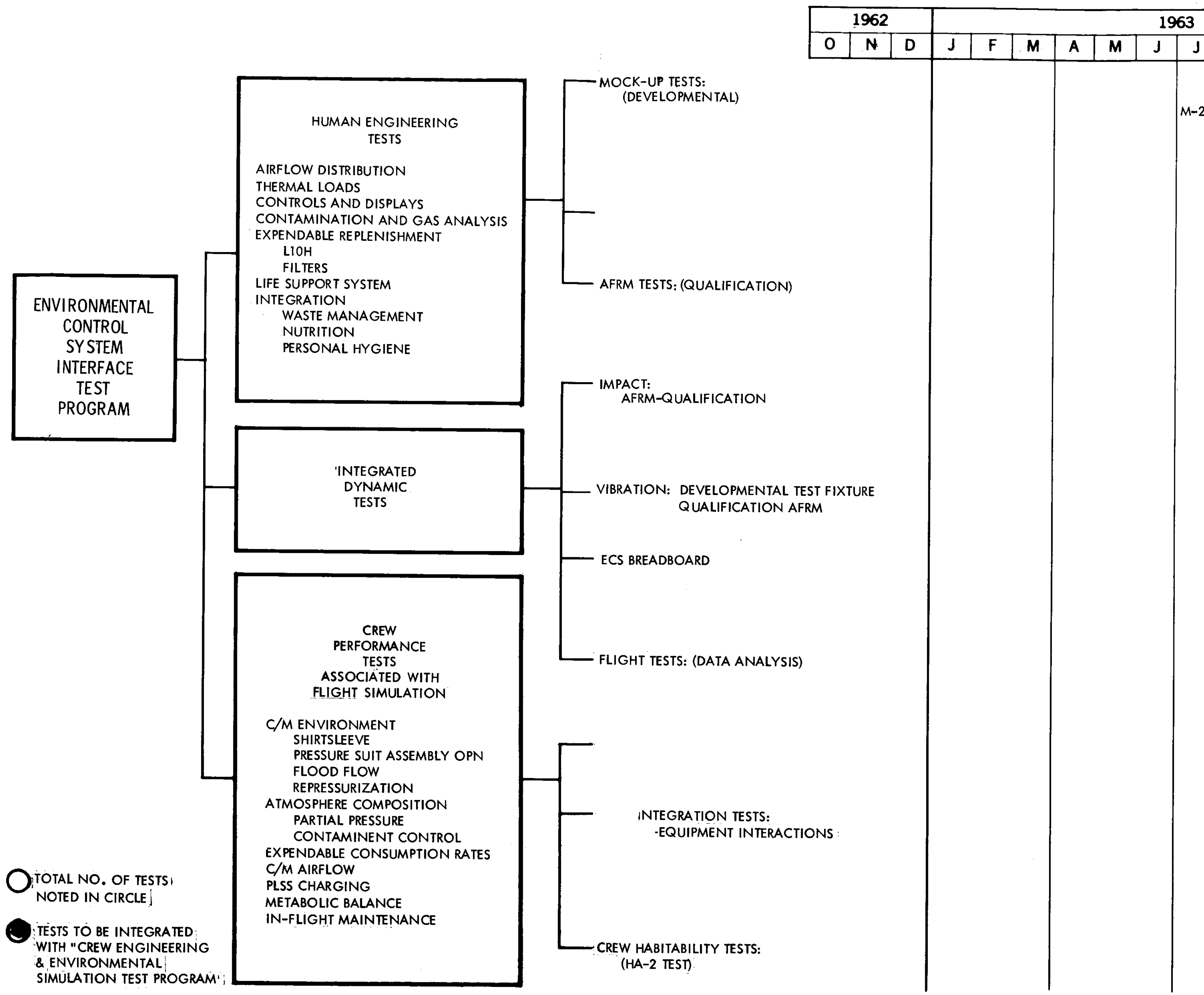
1962
1963
O N D J F M A M J J
M-2
ENVIRONMENTAL CONTROL SYSTEM INTERFACE TEST PROGRAM
HUMAN ENGINEERING TESTS
AIRFLOW DISTRIBUTION
THERMAL LOADS
CONTROLS AND DISPLAYS
CONTAMINATION AND GAS ANALYSIS
EXPENDABLE REPLENISHMENT
LIOH
FILTERS
LIFE SUPPORT SYSTEM INTEGRATION
WASTE MANAGEMENT
NUTRITION
PERSONAL HYGIENE
MOCK-UP TESTS: (DEVELOPMENTAL)
AFRM TESTS: (QUALIFICATION)
INTEGRATED DYNAMIC TESTS
IMPACT: AFRM-QUALIFICATION
VIBRATION: DEVELOPMENTAL TEST FIXTURE
QUALIFICATION AFRM
ECS BREADBOARD
FLIGHT TESTS: (DATA ANALYSIS)
CREW PERFORMANCE TESTS ASSOCIATED WITH FLIGHT SIMULATION
C/M ENVIRONMENT
SHIRTSLEEVE
PRESSURE SUIT ASSEMBLY OPN
FLOOD FLOW
REPRESSURIZATION
ATMOSPHERE COMPOSITION
PARTIAL PRESSURE
CONTAMINENT CONTROL
EXPENDABLE CONSUMPTION RATES
C/M AIRFLOW
PLSS CHARGING
METABOLIC BALANCE
IN-FLIGHT MAINTENANCE
INTEGRATION TESTS: -EQUIPMENT INTERACTIONS
CREW HABITABILITY TESTS: (HA-2 TEST)
TOTAL NO. OF TESTS NOTED IN CIRCLE
TESTS TO BE INTEGRATED WITH "CREW ENGINEERING & ENVIRONMENTAL SIMULATION TEST PROGRAM"

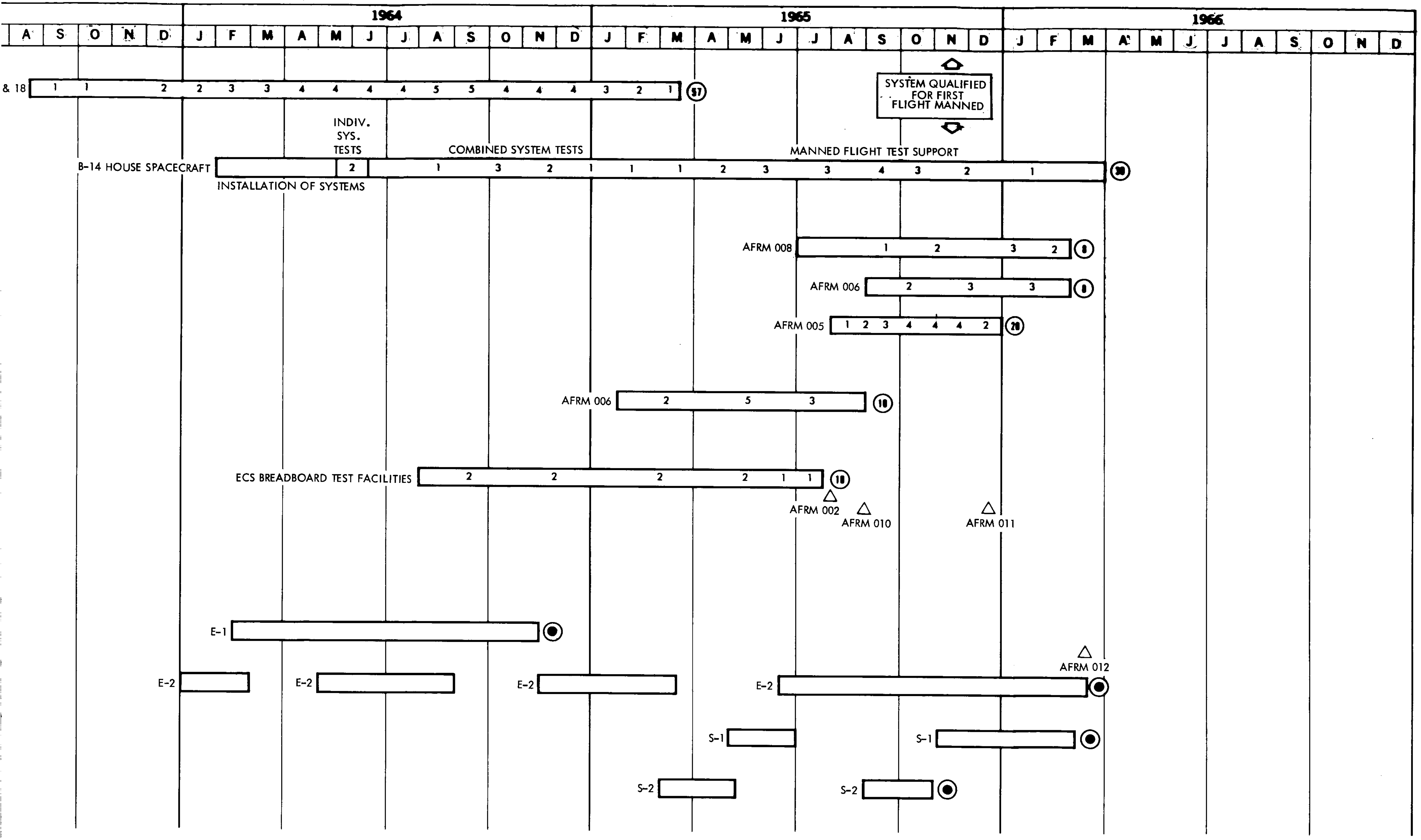

Figure 10-12. Systems Approach—Environmental Control System Test Program

[redacted]

complex. The design of handling equipment will be verified for conformance with performance criteria (S&ID and NASA criteria specifications) for handling and storage of all systems.

10.2.2.6.1.5 Procedures. Performance tests will be conducted to evaluate systems and combined systems checkout procedures. Functions, task, and time-line data will be collected to verify combined systems checkout, procedures design, communications, and safety.

10.2.2.6.1.6 Systems Maintainability. GSE checkout, auxiliary servicing, and handling systems will be evaluated for conformance with human engineering maintainability criteria (S&ID and NASA specifications). Malfunction and alignment simulation tests will verify the over-all design, configuration, and procedures for conformance with GSE systems maintainability criteria.

10.2.2.6.2 <u>Equipment and Facilities.</u> Specific requirements for the GSE (checkout, auxiliary servicing, and handling equipment) systems are as follows:

1. Initial design developmental human engineering tests will be conducted with breadboard mock-ups of GSE control panel and console interfaces, as required, to solve specific problem areas.

2. Integrated systems tests and maintainability and procedures evaluations will be accomplished in conjunction with the house spacecraft test program, Boilerplate 14 and Airframe 006.

3. Functional and operational man-machine compatibility tests will be conducted during the flight test program. (Refer to Volume V.)

10.2.2.6.3 <u>Test Schedule.</u> The GSE test program will be scheduled within the developmental framework shown in Figure 10-13.

10.3 CREW SYSTEMS ENGINEERING AND ENVIRONMENTAL SIMULATION TESTING PROGRAM

The simulation program is designed to assure a successful manned flight on the lunar mission. Preliminary simulations begin with single simplified systems in pertinent manned mission phases, using system components, and progress to more complex and sophisticated prototype equipment for simulation of complete missions.

The major objective of the program is to demonstrate that man-machine interface satisfies command module design criteria. The simulations include evaluation and verification of the displays and controls interface with the flight crew; evaluation of the cabin arrangement, and cabin lighting; and the acceptability of Apollo environment, including food and waste management.

Simulations will also evaluate and verify effects on the flight crew of accelerations, vibration, and noise levels and such special problem as weightlessness, exterior vision, and sun shafting.

Flight crew task assignments will be evaluated and verified by simulations that validate task analysis for crew integration compatibility, correctness of task sequences, work-rest cycles, and flight crew task loadings.

The simulation test program is divided into five mission phases: boost and abort, coast and maneuver, entry, docking, and rendezvous; the Apollo engineering simulation program is divided into three mission phases: dynamic base, system integration, and navigation simulation.

The boost and abort (BA) phase will examine in a logical pattern all aspects of crew operation during boost and abort, beginning with service module abort and retro from orbit, and progressing through service module manual abort and Saturn V emergency modes. LES abort will be a static simulation in support of the dynamic base simulation phase and the portion of crew integration that is related to boost and LES abort. Principle objectives of this phase are to refine the configuration of displays and controls, and the sequence of crew tasks, and to evaluate the level of crew performance.

The crew is an integral part of guidance and control (G&N and SCS) and will be required to monitor the proper functioning of the controls and displays. The coast and maneuver simulation (CM) phase will evaluate these crew operations during earth and lunar orbit and during cislunar flight under SCS and G&N control modes.

[redacted]

TEST ITEM –		HUMAN ENGINEERING FUNCTION DURING TEST
I. PRE-TESTS FOR ACCEPTANCE:		
A. CONTROL DISPLAY PART	1. PANEL: BUTTON, KNOB, LIGHT, METER, SWITCH, ETC a. COMPLIANCE WITH MIL-STD-803 REQUIREMENTS	VISUAL INSPECTION
B. PANEL LAYOUT GEOMETRY AND PARTS FUNCTIONS EVALUATION.	1. PANEL CONFIGURATION: a. COLOR GROUPING, LIGHTING, SPACING, MARKING, ETC 2. FUNCTION COMPATIBILITY: a. INTERPRETATION LIMITATION EXCEEDED	VISUAL INSPECTION
C. COMPONENT PANEL ASSEMBLY (LAYOUT)	1. EVALUATION OF PARTS OF ± A & B	DRAWING REVIEW
D. MAN, EQUIPMENT FUNCTION COMPATIBILITY	1. OPERATIONS PERFORMANCE: TEST PERSONNEL SAFETY EQUIPMENT/APPAREL a. SAFETY FACTORS b. CAPABILITY EXCEEDED c. FUNCTION/BEHAVIOR PECULIARITY	TEST AND OBSERVATION
II. SYSTEMS PERFORMANCE TESTS:		
A. PROFICIENCY STUDY	1. MAN/MACHINE TASK a. EFFICIENCY - MINIMIZED REDUNDANCY, WORK LOAD LIMITATION, MALFUNCTION CORRECTION EFFECTIVENESS, CREW COORDINATION 2. DATA HANDLING AND COMMUNICATIONS EFFECTIVENESS	VERIFY CRITERIA AND MONITOR TEST
B. FUNCTIONAL GROUPING.	1. INTERFACE: CABLING, CONNECTOR MATING a. ANTHROPOMETRY, WORK SPACE CONFIGURATION 2. MARKING: a. COMPLIANCE WITH HUMAN ENGINEERING REQUIREMENTS, USE OF PLACARDS	ESTABLISH REQUIREMENT AND MONITOR APPLICATION
C. PERFORMANCE-MAN EQUIPMENT OPERATIONAL COMPATIBILITY	1. OPERATOR: COMPREHENSIVENESS, FATIGUE, SKILL LEVEL, TEAM COORDINATION, CAPABILITY EXCEEDED, ALERTNESS 2. EQUIPMENT: CONTROL/DISPLAY ACTION EXCEEDS HUMAN COMPREHENSION. 3. MAN/EQUIPMENT: HANDICAP, IMPROPER TOOL OR USE, FUNCTION CONTINUITY	OBSERVE FOR REQUIREMENT VERIFICATION
D. ENVIRONMENTAL DISTRACTION	1. CLIMATIC 2. MAN-MADE: a. ILLUMINATION, NOISE, TEMPERATURE, HUMIDITY, RADIATION, ETC b. TOXIC GAS, ODOR, BLINKING LIGHT, AND INTERRUPTION, COMPLIMENT RESTRICTION	MONITOR AREA
E. COMPLIANCE WITH TEST CRITERIA	1. CHECKLIST ITEMS: ITEMS TO BE CONSIDERED DURING TESTS 2. DOCUMENTATION: LSTR'S, REPORTS 3. DATA HANDLING: DATA ACQUISITION, CODING, PROCESSING, AND ACKNOWLEDGEMENT	SURVEILLANCE FOR OPERATOR HUMAN FACTORS APPLICATION
III. SYSTEMS MAINTAINABILITY:		
A. CALIBRATION, TROUBLESHOOTING, & PARTS REPLACEMENT ACCESSIBILITY (ANALYSIS)	1. ANTHROPOMETRY: WORK SPACE ALLOCATION 2. PROPER TOOL: SERVICING, HANDLING, CALIBRATION, AND REPAIR OPERATIONS 3. EFFICIENCY ITEM: TOOL HOLDER (AVAILABILITY); BRACKET FOR TEST EQUIPMENT 4. INTERCHANGEABILITY: SPARE, STANDARD PART, MARKING	ANALYSIS VERIFICATION
B. MAINTENANCE PERFORMANCE	1. COMPREHENSIVENESS: TIME/MOTION STUDY 2. ALERTNESS 3. MOTIVATION	VALIDATION CHECK
C. COMPLIANCE WITH GOOD HOUSEKEEPING PRACTICE	1. CHECK HOUSEKEEPING EQUIPMENT: VACUUM CLEANER, RAG CONTAINER, ETC a. STOWAGE AREA: SPONTANEOUS COMBUSTION PREVENTION	MONITOR PROCEDURE
IV. COMMON CHECKS.		
A. DATA HANDLING	1. EFFECTIVENESS: a. USE OF DATA SYSTEM b. USE OF EQUIPMENT HISTORY CARDS c. CODING METHOD, DATA PROCESSING METHOD	MONITOR SYSTEM
B. MALFUNCTION AND PROBLEM	1. CHECK USE OF NCR'S AND NCAR'S 2. CHECK COMMUNICATIONS EFFECTIVENESS	MONITOR SYSTEM
C. COMPLIANCE WITH COMMUNICATIONS PROCEDURE	1. SURVEY "HOT SPOTS" IN COMMUNICATION BREAKS 2. MAKE COMPLETENESS SURVEY	SURVEY COMMUNICATIONS CHAIN
D. PHYSIOLOGICAL DEMANDS EQUIPMENT	1. CHECK AREA FOR AVAILABILITY OF BIOPHYSICAL EQUIPMENT a. FACILITY: DRINKING WATER, REST ROOM, ETC, HYGIENE b. REST PERIOD, SANITARY EATING AREA	COMPARE CODE WITH FACILITY REGULATIONS
E. SAFETY PRACTICE	1. EMERGENCY EVALUATION: a. EXIT MARKING, OVERVIEW OF TEST COMPLEX b. DECONTAMINATION MEASURE, SHOWER 2. AREA CLEARANCE: CABLING/PLUMBING, OILY/WET FLOOR	SAFETY MONITORING
F. COMFORT	1. CONVENIENCE OUTLET: ELECTRICAL METER, SOLDERING IRON, ETC 2. PERSONNEL EQUIPMENT: FLASHLIGHT, SUN GLASSES, ETC	SURVEY AREA BETWEEN TESTS

APOLLO VEHICLE BEING TESTED BY GSE

MOCK-UP NO. 9 AND 11

BOILERPLATE NO.:
- 6 (C/M PAD ABORT)
- 9 (VEHICLE FOR DYNAMIC TESTS)
- 12 (C/M MAX Q - LES VERIFICATION)
- 13 (1ST S/C FOR LAUNCH ENVIRONMENT)
- 14 (HOUSE SPACECRAFT NO. 1)
- 15 (2ND VEHICLE FOR LAUNCH ENVIRONMENT)
- 16 (VEHICLE FOR MICROMETEROID EXPERIMENT)
- 22 (HIGH-ALTITUDE ABORT)
- 23 (BACKUP FOR BP-6, BP-12)

AIRFRAME NO.
- 001 (PROPULSION SYSTEM QUAL S/M ONLY)
- 002 (C/M FOR MAX q ABORT AND C/M STRUCTURAL DEMONSTRATION)
- 006 (HOUSE SPACECRAFT NUMBER 2)
- 009 (UNMANNED QUALIFICATION FLIGHT)
- 010 (C/M FOR PAD ABORT)
- 011 (S/C FOR 1ST MANNED FLIGHT)

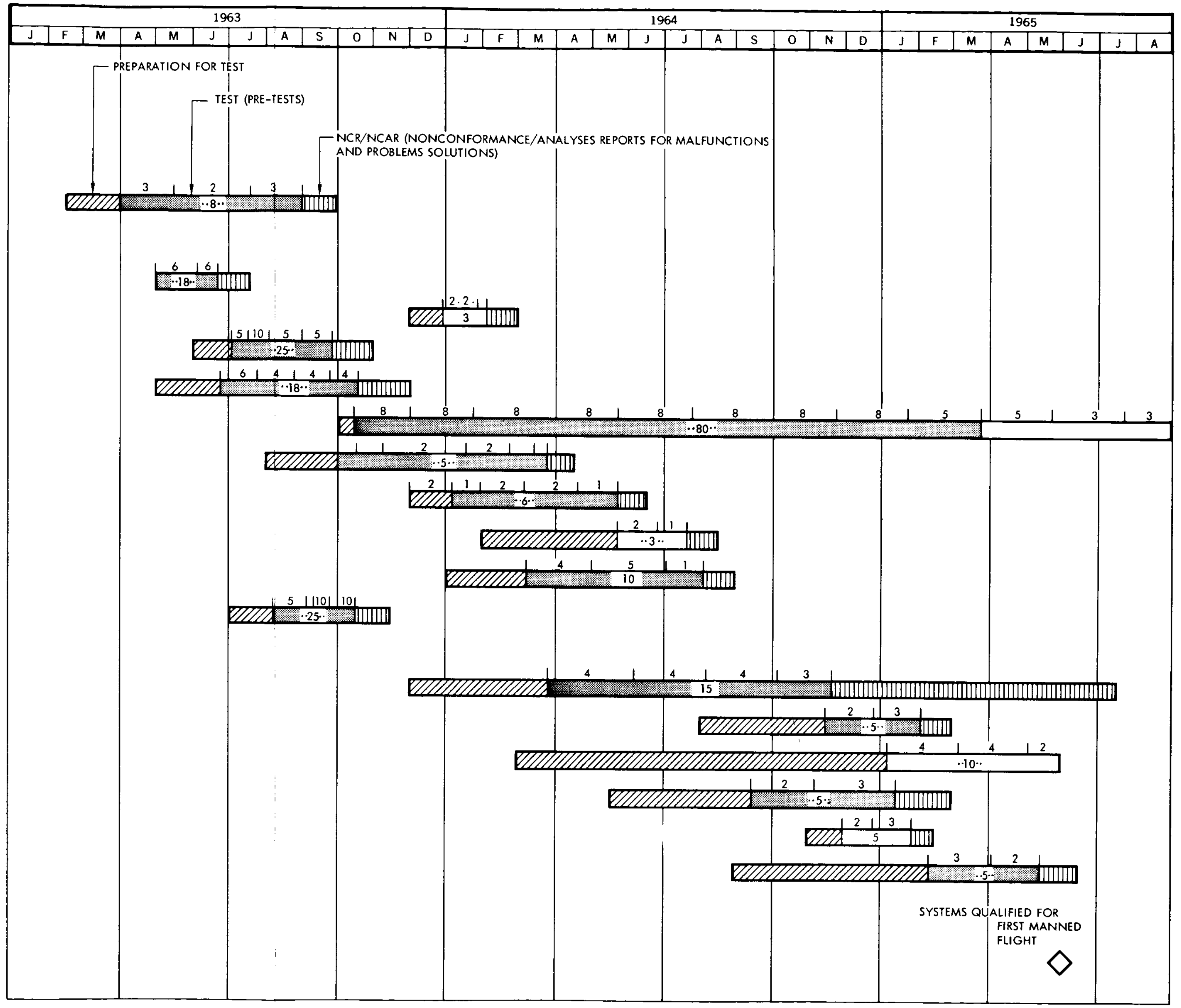

Figure 10-13. Human Engineering Function Schedule for Apollo GSE Tests

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The entry simulation (EN) phase will determine possible problems resulting from interactions of the equipment or environment with the crew, including entry profiles, controls and displays, and system contingencies of orbital and lunar return entry envelopes. Entry is a critical part of the flight because of stringent accuracy requirements for spacecraft attitude and time of arrival at the atmosphere, and the anticipated stresses imposed upon the crew.

Because of the criticality of LEM operations, two separate simulation phases, docking (D) and rendezvous (R), are scheduled. The docking phase will investigate the crew capability to determine the angle between the interceptor velocity vector and the line of sight, the approximate time to intercept, and lags associated with thrust buildup in the attitude jets. A major consideration of the docking phase is the evaluation and development of sighting devices, alignment aids, and pilot techniques. Stringent accuracy requirements exist with respect to angle and timing of rendezvous. Crew capability to determine the rate of propellant consumption for the variable thrust engine aligned along the interceptor body axis will be studied in the rendezvous phase. Requirements for number of ΔV and orbital angle corrections will be evaluated.

Critical systems for boost, abort, and entry will be further verified during the dynamic base simulations (DY), which include two manned centrifuge simulations and one group of shake table tests. These tests will also contribute valuable psychological and physiological data with respect to crew performance capabilities, visibility and legibility of displays, and will help to determine human tolerance to vibration and acceleration loads.

Qualification testing (QU) of airframe vehicles will follow the evaluation and verification tests of all simulations and house spacecraft.

Supplementing the critical mission phase integration studies will be a system integration (IN) simulation phase, in which contingencies, in-flight maintenance, and pressure garment donning and operations will be emphasized. One of the tests to be conducted will use a single subject for studying one-man earth return operations. Each airframe vehicle test design for a manned mission is programmed for a systems integration (task analysis verfication) test. Refinement in crew interaction, task loading, and task analysis verification will also be accomplished in the IN series.

Crew Systems requirements for the G&N simulation (NA) series include the need for evaluating various parameters of crew and systems performance on individual tasks and on integrated sequences of tasks. The phase will start with the most critical navigational tasks performed by one man and progress to those tasks performed by the entire crew, including complete G&N tasks at appropriate points in the mission.

10.3.1 Mission Phases

10.3.1.1 Boost and Abort Phase

10.3.1.1.1 Boost and LES Abort. (Simulation of the critical mission launch, boost, and LES abort phases)

10.3.1.1.1.1 Objectives. The objectives of this phase are:

1. Statically evaluate problems discovered during the abort portion of the Phase I centrifuge program
2. Evaluate techniques for manual operation of spacecraft systems during LES abort
3. Evaluate the ability of the pilot to initiate RCS fuel and oxidizer dump and LES procedures during the post-abort period
4. Validate task analysis for correct sequence of tasks
5. Evaluate task loading
6. Evaluate the effects of equipment design and functional arrangements on the crew performance.

10.3.1.1.1.2 Test Plan

10.3.1.1.1.2.1 Tasks. The tasks to be performed are:

1. Monitor displays during the critical phases of launch and boost
2. Initiate LES abort sequence upon detecting a critical spacecraft systems failure
3. Initiate emergency manual backup abort system if failure in manual abort system occurs
4. Perform post-abort procedures.

10.3.1.1.1.2.2 Variables. The variables are:

1. Manual versus manual backup of LES abort system
2. Pressure garment — pressurized versus non-pressurized.

10.3.1.1.1.2.3 Measurements. The measurements to be made include:

1. Time required to detect possible abort situation
2. Time required to initiate abort sequence
3. Accuracy of manual abort and post-abort procedure
4. Accuracy of task analysis procedures.

10.3.1.1.1.3 Equipment Requirements. The equipment required is as follows:

1. Latest Apollo controls and displays
2. Pressure garment assembly
3. Crew couches
4. Communication equipment
5. Computers: To be determined.

10.3.1.1.1.4 Facilities: Evaluator E-2, S&ID, Downey.

10.3.1.1.1.5 Test Schedule: November and December 1964 (see Figure 10-14).

10.3.1.1.2 <u>Service Module Abort I.</u> (Simulation of important spacecraft systems in a single-plane trajectory.) BA-1

10.3.1.1.2.1 Objectives. The objectives of this phase are:

1. Evaluate techniques for manual operations of the spacecraft systems during service module abort
2. Evaluate G&N, SCS, C&D, and manual capability for performing the basic service module abort maneuvers

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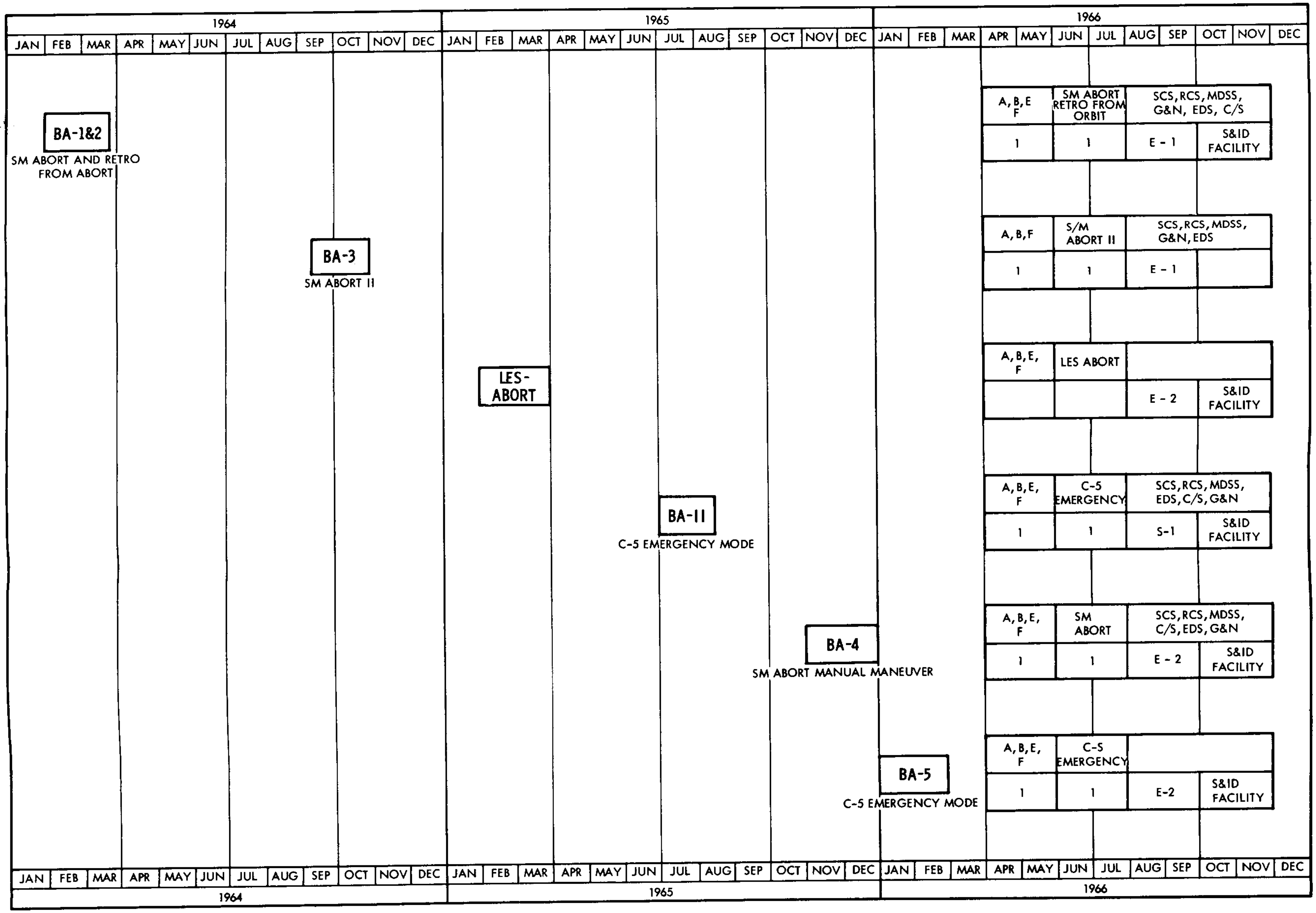

Figure 10-14. Mission Phases Boost and Abort Test Schedule

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3. Evaluate automatic and manual failure detection and switching

4. Evaluate the adequacy of available back-up or redundant systems

5. Validate task analysis for the correct sequence of tasks

6. Evaluate task loading.

10.3.1.1.2.2 Test Plan

10.3.1.1.2.2.1 Tasks. The tasks to be performed are:

1. Monitor displays during boost

2. Initiates service module abort sequence upon detecting a spacecraft systems failure

3. Perform mode selection within required sequencing times.

10.3.1.1.2.2.2 Variables. The variables are:

1. Pressure garment — pressurized versus non-pressurized

2. Malfunctions necessitating abort versus malfunctions in which abort is not required.

10.3.1.1.2.2.3 Measurements. The measurements to be made include:

1. Time required to detect possible abort situations

2. Time required to initiate abort sequence

3. Accuracy of response (abort versus malfunction correction)

4. Accuracy of task analysis procedures.

10.3.1.1.2.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle: Evaluator E-1

2. Latest Apollo controls and displays

3. Pressure garment assembly

4. Crew couches

5. Communications

6. Computers: Analog.

10.3.1.1.2.4 Facilities: Evaluator E-1; S&ID, Downey

10.3.1.1.2.5 Test Schedule: February and March 1964

10.3.1.1.3 Retro from Orbit. (A 6 DOF trajectory study for evaluation of overall system accuracy and operation for retro from earth orbit with both SPS and RCS.) BA-2

10.3.1.1.3.1 Objectives. The objectives of this phase are:

1. Evaluate the error involved in crew-controlled normal G&N and combined spacecraft systems dynamics during SPS powered retro from earth orbit

2. Evaluate crew-controlled pre-entry dynamics (command module service module separation maneuver) following normal retro from orbit

3. Evaluate crew-controlled emergency modes for retro

4. Validate task analysis for correct sequence of tasks

5. Evaluate task loading.

10.3.1.1.3.2 Test Plan

10.3.1.1.3.2.1 Tasks. The tasks to be performed are:

1. Monitor displays during pre-entry

2. Maneuver the spacecraft to retro attitude and initiate retro sequence

3. Initiate command module service module separation.

10.3.1.1.3.2.2 Variables. The variables are:

1. Pressure garment — pressurized versus non-pressurized

2. Various entry alignment angles

3. Various emergency conditions.

10.3.1.1.3.2.3 Measurements. The measurements to be made include:

1. Time required to detect a possible emergency situation

2. Time required to complete the retro sequence

3. Accuracy of pre-entry position

4. Accuracy of response

5. Accuracy of task analysis procedures.

10.3.1.1.3.3 Equipment Requirements. The equipment required is as follows:

1. Latest Apollo controls and displays

2. Pressure garment assembly

3. Crew couches

4. MDSS communications

5. Video coverage

6. Data acquisition equipment: To be compatible with AP701-Analysis of Variance Program.

10.3.1.1.3.4 Facilities: Evaluator E-1, S&ID, Downey

10.3.1.1.3.5 Schedule: February and March 1964

10.3.1.1.4 Service Module Abort II. (A 6 DOF trajectory study to evaluate systems design for service module abort, in terms of crew and systems design compatibility and manual or automatic procedures.) BA-3

10.3.1.1.4.1 Objectives. The objectives of this phase are:

1. Evaluate the compatibility of the G&N, SCS, and displays and controls for crew usage in the tumbling environment of service module abort
2. Evaluate manual sequencing capabilities following abort
3. Evaluate service module command module separation maneuver and manual attitude orientation with and without spacecraft attitude reference
4. Validate task analysis for correct sequence of tasks
5. Evaluate task loading.

10.3.1.1.4.2 Test Plan

10.3.1.1.4.2.1 Tasks. The tasks to be performed are:

1. Monitor displays during launch and boost
2. Initiate service module abort sequence upon detecting a critical spacecraft systems failure
3. Initiate service module command module separation and stabilize attitude

10.3.1.1.4.2.2 Variables. The variables are:

1. Tumbling rates
2. Pressure garment — pressurized versus non-pressurized
3. Various cues for command module orientation
4. Manual versus automatic stabilization.

10.3.1.1.4.2.3 Measurements. The measurements to be made include:

1. Time to dampen tumbling
2. Time to reorient to entry angle
3. Position error in pitch, roll, and yaw
4. Fuel usage
5. Accuracy of task analysis procedures.

10.3.1.1.4.3 Equipment Requirements. The equipment required is as follows:

1. Latest Apollo controls and displays
2. Pressure garment assembly
3. Crew couches
4. Communication equipment
5. Video coverage
6. External earth horizon visual display
7. Sun shafting equipment
8. Computers: To be determined.

10.3.1.1.4.4 Facilities: Evaluator E-2, S&ID, Downey

10.3.1.1.4.5 Schedule: July and August 1964

10.3.1.1.5 <u>Service Module Abort – Manual Maneuvers</u>. (A 6 DOF trajectory study to evaluate maneuver capabilities for service module abort.) BA-4

10.3.1.1.5.1 Objectives. The objectives of this phase are:

1. Evaluate compatibility between EDS and service module abort systems

2. Evaluate task analysis abort procedures

3. Evaluate various decision making aids and techniques for contingency operation

4. Validate task analysis for correct sequence of tasks

5. Evaluate task loading.

10.3.1.1.5.2 Test Plan.

10.3.1.1.5.2.1 Tasks. The tasks to be performed are:

1. Monitor displays during launch and boost

2. Initiate service module abort sequence upon detecting a critical spacecraft systems failure from S-I boost

3. Initiate service module command module separation and perform stabilizing maneuvers.

10.3.1.1.5.2.2 Variables. The variables are:

1. Tumbling rates

2. Pressure garment — pressurized versus non-pressurized

3. Various cues for command module orientation

4. Manual versus automatic stabilization

10.3.1.1.5.2.3 Measurements. The measurements to be made include:

1. Time to dampen tumbling

2. Time to reorient to entry angle

3. Position error in pitch, roll, and yaw.

4. Fuel usage

5. Accuracy of task analysis procedures.

10.3.1.1.5.3 Equipment Requirements. The equipment required is as follows:

1. Latest Apollo controls and displays

2. Pressure garment assembly

3. Crew couches

4. Communications

5. Video coverage

6. External earth horizon visual display

7. Sun shafting

8. Computers: To be determined.

10.3.1.1.5.4 Facilities: Evaluator E-2, S&ID, Downey

10.3.1.1.5.5 Schedule: March and April 1965

10.3.1.1.6 <u>Saturn V Emergency Modes.</u> (A study of the use of spacecraft systems and operational techniques for maneuvers associated with aborts and spacecraft systems failures for the lunar mission.) BA-5

10.3.1.1.6.1 Objectives. The objectives of this phase are:

1. Evaluate Saturn V EDS, crew, and spacecraft compatibility

2. Evaluate task analysis abort procedures for Saturn V

3. Evaluate crew-controlled service module command module separation, maneuver, and attitude orientation

4. Validate task analysis for correct sequence of tasks

5. Evaluate task loading.

[redacted]

10.3.1.1.6.2 Test Plan

10.3.1.1.6.2.1 Tasks. The tasks to be performed are:

1. Monitor displays during the Saturn V launch and boost

2. Initiate service module abort sequence upon detecting a critical spacecraft systems failure

3. Initiate service module command module separation and stabilize attitude.

10.3.1.1.6.2.2 Variables. The variables are:

1. Tumbling rates

2. Pressure garment — pressurized versus non-pressurized

3. Various cues for command module orientation

4. Manual versus automatic stabilization.

10.3.1.1.6.2.3 Measurements. The measurements to be made include:

1. Time required to dampen tumbling

2. Time required to reorient vehicle to the proper entry angle

3. Position error in pitch, roll, and yaw

4. Fuel usage

5. Accuracy of task analysis procedures.

10.3.1.1.6.3 Equipment Requirements. The equipment required is as follows:

1. Latest Apollo controls and displays

2. Pressure garment assembly

3. Crew couches

4. MDSS communications

5. Video coverage

6. External earth horizon visual display

7. Sun shafting equipment

8. Computers: To be determined.

10.3.1.1.6.4 Facilities: Evaluator E-2, S&ID, Downey

10.3.1.1.6.5 Schedule: October and November 1965

10.3.1.1.7 Saturn V Emergency Modes. (A 6 DOF simulation to evaluate the lunar vehicle design concept in terms of service module abort and near earth emergency maneuver requirements, using prototype equipment.) BA-II

10.3.1.1.7.1 Objectives. The objectives of this phase are:

1. Evaluate EDS and CSS emergency manual decision-making aids

2. Evaluate the extent to which external visual displays can be used to supplement spacecraft systems for abort situations

3. Evaluate the interface of controls and displays with manual and automatic abort mechanization

4. Validate task analysis for the correct sequence of tasks

5. Evaluate task loading

6. Validate task analysis for crew integration compatibility.

10.3.1.1.7.2 Test Plan

10.3.1.1.7.2.1 Tasks. The tasks to be performed are:

1. Monitor displays during the Saturn V launch and boost

2. Initiate service module abort sequence upon detecting a critical spacecraft system failure

3. Initiate service module command module separation and stabilize attitude.

10.3.1.1.7.2.2 Variables. The variables are:

1. Tumbling rates
2. Pressure garment — pressurized versus non-pressurized
3. Various cues for command module orientation
4. Manual versus automatic stabilization.

10.3.1.1.7.2.3 Measurements. The measurements to be made include:

1. Time required to dampen tumbling
2. Time required to reorient vehicle to the proper entry angle
3. Position error in pitch, roll, and yaw
4. Fuel usage
5. Accuracy of task analysis procedures.

10.3.1.1.7.3 Equipment Requirements. The equipment required is as follows:

1. Latest Apollo controls and displays
2. Pressure garment assembly
3. Crew couches
4. MDSS communications
5. Video coverage
6. External earth horizon visual display
7. Sun shafting equipment
8. Computers: To be determined

10.3.1.1.7.4 Facilities: Simulator S-1, S&ID, Downey

10.3.1.1.7.5 Schedule: July and August 1965

10.3.1.2 Coast and Maneuver Phase

10.3.1.2.1 Coast and Maneuver 1. (A 3 DOF simulation to evaluate the pilot's performance during four mission phases under SCS and G&N modes.) CM-1

10.3.1.2.1.1 Objectives. The objectives of this phase are:

1. Determine the effects of different spacecraft configurations and maneuver rates in making various attitude changes on service module RCS propellant consumption

2. Evaluate the ability of the pilot subject to achieve and maintain different maneuver rates with various spacecraft configurations while using various attitude changes modes

3. Evaluate the ability of the pilot subject to make various changes and maintain attitude stability, using the visual starfield (left viewing window) for attitude reference

4. Determine the best crew procedures for making spacecraft attitude maneuvers with various spacecraft configurations and maneuver rates

5. Determine the effects of the systems uncertainties on service module RCS propellant consumption and attitude and rate error as follows:

   a. Rate gyro null uncertainty

   b. Service module RCS jet on/off delay time.

10.3.1.2.1.2 Test Plan

10.3.1.2.1.2.1 Tasks. The tasks to be performed are:

1. Maneuver the spacecraft from one attitude to another specified attitude in three axes by manipulating the attitude controller.

10.3.1.2.1.2.2 Variables. The variables are:

1. Configuration
2. Maneuver rate
3. Axis of change
4. Amount of attitude change

5. Rate gyro null offset
6. Service module RCS engine cant
7. Pseudo rate time delay
8. Service module RCS quad failures
9. Starfield angle of attitude change
10. Shirtsleeve versus pressure garment assembly (pressurized and vented).

10.3.1.2.1.2.3 Measurements. The measurements to be made include:

1. Maneuver rate error in three axes
2. Fuel in three axes
3. Final body rate in three axes
4. Final attitude error in three axes
5. Run time.

10.3.1.2.1.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle: Evaluator 2
2. Command module interior:
    a. Latest Apollo design instrument panel
    b. Latest Apollo design attitude controller
    c. Pressure garment assembly, including provisions for vent air or breathing air
    d. Command Module communications system
3. Special Equipment: Dynamic starfield
4. Computers: Analog computer tie-in.

10.3.1.2.1.4 Facilities: Evaluator 2, S&ID, Downey

10.3.1.2.1.5 Test Schedule: January through March 1964 (Figure 10-15)

10.3.1.2.2 Coast and Maneuver 2. (A 6 DOF simulation study to evaluate pilot performance during four mission phases.) CM-2

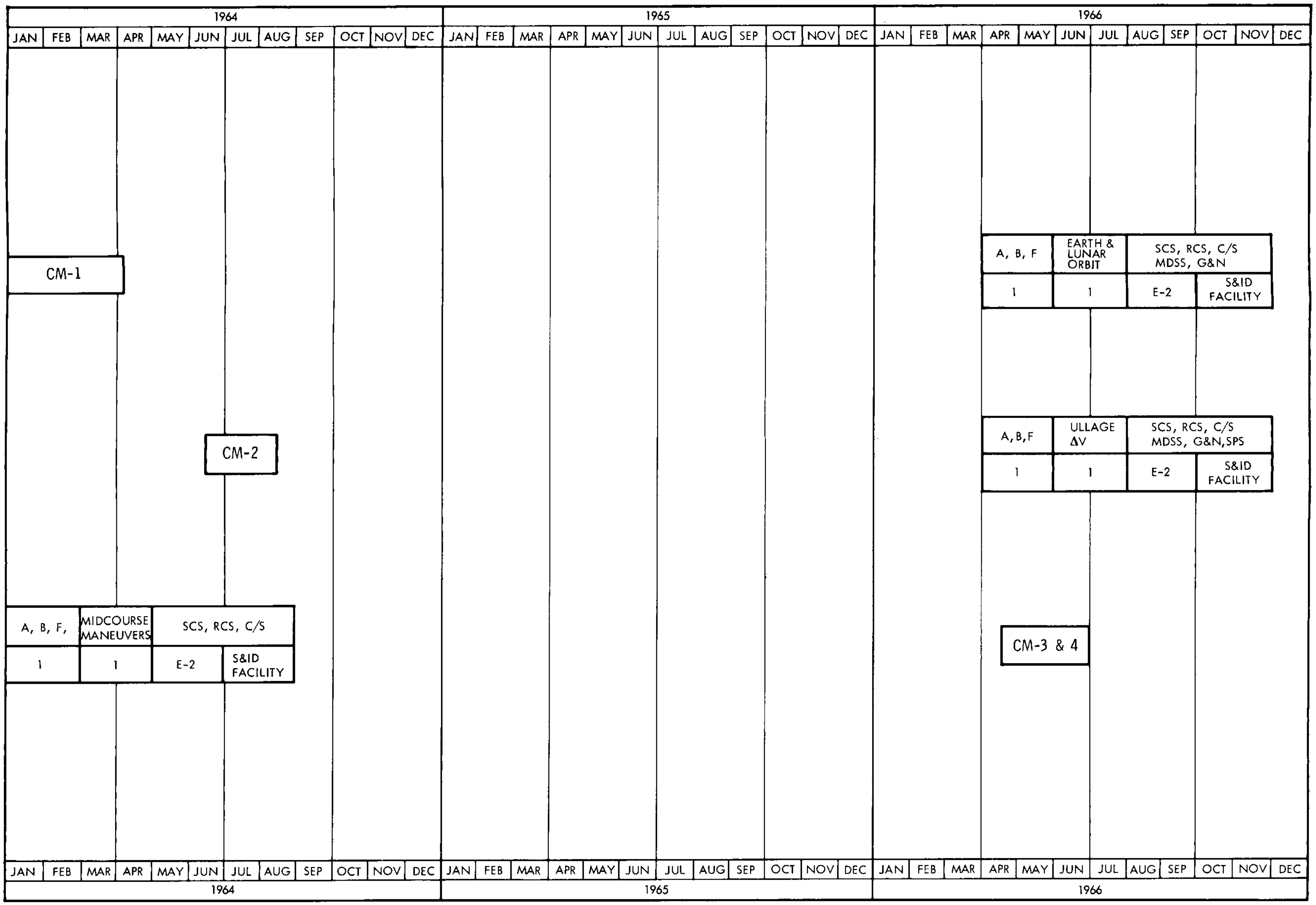

Figure 10-15. Mission Phases Coast and Maneuvers Test Schedule

10.3.1.2.2.1 Objectives. The objectives of this phase are:

1. Evaluate pilot subject ability to perform attitude maneuvers using a prototype FDAI as a reference

2. Evaluate pilot subject ability to perform midcourse navigation attitude maneuvers at the lower equipment bay (LEB), using the starfield as a reference

3. Evaluate hand-controller design for attitude impulse control at the LEB

4. Evaluate pilot subject ability to perform attitude maneuvers under system component failures

5. Validate task analysis for correct sequence of tasks

6. Evaluate task loading.

10.3.1.2.2.2 Test Plan.

10.3.1.2.2.2.1 Tasks. The crewmen will be required to perform the following tasks:

1. Maneuver the spacecraft to take sightings of landmarks and celestial bodies

2. Maneuver the spacecraft for attitude maneuvers during the four mission phases using the main display console

3. Manually perform any ullage maneuvers required for all velocity changes during the four mission phases

4. Monitoring and setting the main panel displays and controls, and manipulating the attitude and translational controllers.

10.3.1.2.2.2.2 Variables. The variables are:

1. Spacecraft weight/mass configuration (CM + SM versus CM + SM + full LEM)

2. Various initial conditions

3. Hand-controller design for the minimum impulse control

4. Pressure garment assembly (PGA) versus shirtsleeve conditions

5. System failures.

10.3.1.2.2.2.3 Measurements. The measurements to be made include:

1. Total fuel consumption for RCS and SPS

2. Final rates

3. Time required to perform attitude maneuvers

4. Final attitude maneuver error

5. Navigation sighting error

6. Attitude control reversals

7. Accuracy of task analysis procedures.

10.3.1.2.2.3 Equipment Requirements. The equipment required is as follows:

1. Command Module Interior:

    a. Latest Apollo design instrument panel and controls

    b. Latest Apollo design attitude and translational controls

    c. Pressure garment assembly (pressurized and unpressurized), including provisions for vent air or breathing air

    d. Command Module communications system

2. Special Equipment: Random starfield

3. Computers: Analog.

10.3.1.2.2.4 Facilities: Evaluator 2, S&ID, Downey

10.3.1.2.2.5 Test Schedule: July and August 1964

[redacted]

10.3.1.2.3 Coast and Maneuver 3. (A 3 DOF simulation to evaluate crew performance during translunar coast and transearth coast.)

10.3.1.2.3.1 Objectives. The objectives of this phase are:

1. Evaluate crew accuracy in performing mid-course attitude orientation maneuvers:

   a. IMU alignment

   b. Navigational sightings

   c. Other attitude requirements

2. Evaluate navigation techniques, using G&N equipment during translunar coast and transearth coast

3. Validate integrated task analysis of mid-course navigational sightings

4. Validate task analysis for correct sequence of tasks

5. Evaluate task loading.

10.3.1.2.3.2 Test Plan.

10.3.1.2.3.2.1 Tasks. The tasks to be performed are:

1. Maneuver the spacecraft to take navigational sightings as required for IMU alignment

2. Operate the navigational sighting equipment to obtain celestial fixes for IMU alignment.

10.3.1.2.3.2.2 Variables. The variables are:

1. Spacecraft weight/mass configurations

2. Pressure garment vented versus pressure garment pressurized versus shirtsleeve condition

3. Minimum impulse and optics control configurations

[redacted]

4. Minimum impulse and optics control rates

5. Initial conditions of spacecraft and optics shaft and trunnion angles

6. Direct versus resolved mode for optics controller

7. Optics reticle configuration

8. Position of the mark button.

10.3.1.2.3.2.3 Measurements. The measurements to be made include:

1. Final attitude error

2. Residual body axis drift

3. Angular error of navigational star fix

4. Time and fuel usage for attitude maneuvers prior to acquisition

5. Time and fuel usage for acquisition maneuvers using minimum impulse control and optics controller

6. Direction and number of erroneous commands

7. Accuracy of task analysis procedures.

10.3.1.2.3.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle: Evaluator 2

2. Command Module Interior:

    a. Latest Apollo design instrument panel and controls, including LEB

    b. Latest Apollo design attitude controls

    c. Pressure garment assembly (pressurized and unpressurized), including provisions for vent air or breathing air

    d. Command module communication system.

3. Special equipment:

   a. Dynamic starfield

   b. Telescope and sextant

   c. Breadboard G&N system

4. Computers: Analog and digital computer tie-in.

10.3.1.2.3.4 Facilities: Evaluator 2, S&ID, Downey

10.3.1.2.3.5 Test and Schedule: April 1966

10.3.1.2.4 Coast and Maneuver 4. (A 6 DOF simulation to evaluate crew performance during mid-course ΔV corrections.) CM-4

10.3.1.2.4.1 Objectives. The objectives of this phase are:

1. Evaluate techniques for making ΔV corrections based on data derived from G&N, AGC, MDSS, and DSIF

2. Evaluate accuracy of mid-course attitude orientation maneuvers under near planet conditions for:

   a. Star-landmark sightings

   b. IMU alignments

   c. Other attitude requirements

3. Validate integrated task analysis for mid-course ΔV corrections

4. Validate task analysis for correct sequence of tasks

5. Evaluate task loading

6. Validate task analysis for crew integration compatibility.

10.3.1.2.4.2 Test Plan.

10.3.1.2.4.2.1 Tasks. The tasks to be performed are:

1. Maneuver the spacecraft to take navigational sightings required for IMU alignment

2. Operate the navigational sighting equipment to obtain celestial fixes required for IMU alignment and trajectory corrections

3. Compute requirements for and manually make TVC settings necessary to perform the ΔV maneuver required for trajectory correction, utilizing data acquired from navigational sightings, MDSS, and DSIF.

10.3.1.2.4.2.2 Variables. The variables are:

1. Spacecraft weight/mass configurations

2. Pressure garment vented versus pressure garment pressurized versus constant wear garment

3. Minimum impulse and optics control configurations

4. Minimum impulse and optics control rates

5. Initial conditions of spacecraft attitude and of optics shaft and trunnion angles

6. Direct versus resolved mode for optics controller

7. Optics reticle configurations

8. Position of mark button.

10.3.1.2.4.2.3 Measurements. The measurements to be made include:

1. Final spacecraft attitude error

2. Residual body axis drift rates

3. Error in star-landmark alignment

4. Time and fuel required for attitude maneuvers prior to navigational sightings

5. Time required to accomplish navigational sighting, using sextant telescope

6. RCS fuel required during period of navigational sighting, utilizing minimum impulse hand controller

7. Accuracy of task analysis procedures.

10.3.1.2.4.3 Equipment Requirements. The equipment required is as follows:

1. Command Module Interior:

   a. Latest Apollo design instrument panel and controls, including LEB

   b. Latest Apollo design attitude and translational controllers

   c. Pressure garment assembly including provisions for vent air or breathing air

2. Special Equipment:

   a. Dynamic starfield

   b. Telescope and sextant

   c. Near-earth visual display

   d. Far-earth visual display

   e. Near-moon visual display

   f. Far-moon visual display

   g. Breadboarded G&N system.

3. Computers: Analog and digital computer tie-in.

10.3.1.2.4.4 Facilities: Evaluator 2, S&ID, Downey

10.3.1.2.4.5 Test Schedule: April 1966

10.3.1.3 Entry Phase

10.3.1.3.1 Entry Simulation Study I. (Simulation and evaluation of orbital and suborbital entry envelopes, and SCS and RCS failure effects, with man in the loop.) EN-1

10.3.1.3.1.1 Objectives. The objectives of this phase are:

1. Determine the possible problem areas resulting from interactions of system contingencies, entry profiles, and controls and displays with crew tasks

2. Determine the ability of the pilot subject to identify malfunctions in systems that will require emergency manual control of the Command Module during the entry phase

3. Determine the accuracy of manual attitude control during entry, using the manual and emergency manual system

4. Evaluate the capability of the pilot subject to perform ELS procedures

5. Validate task analysis for correct sequence of tasks

6. Evaluate task loading during entry phases.

10.3.1.3.1.2 Test Plan.

10.3.1.3.1.2.1 Tasks. The tasks to be performed are:

1. Monitor displays and controls during the entry phase

2. Activate emergency manual override if contingency requires.

10.3.1.3.1.2.2 Variables. The variables are:

1. Various entry angles

2. Various contingencies

3. Shirt sleeve versus pressure garment assembly

4. Various entry profiles.

10.3.1.3.1.2.3 Measurements. The measurements to be made include:

1. Computed maximum G's

2. Computed G — onset

3. Computer G — duration at different levels

4. Reaction time

5. Amount of time trace is tangent or greater than tangent to the radial lines on the display

6. Accuracy of roll attitude

7. Total fuel consumption

8. Accuracy of task analysis procedures.

10.3.1.3.1.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle: E-1

2. Roll indicator

3. FDAI

4. Rate needles

5. Rotational controller

6. Closed-circuit TV

7. X-Y plotter

8. Analog and digital computer with converters

9. 15- to 20-channel pen recorder.

10.3.1.3.1.4 Facilities: Evaluator 1, S&ID, Downey

10.3.1.3.1.5 Schedule: July to September 1963 (completed)

10.3.1.3.2 Entry Simulation Study 2. (Simulation and evaluation of the entry monitor display; reorientation after tumbling; and SCS, RCS, G&N malfunction interaction during entry from orbital missions, with man in the loop.) EN-2

10.3.1.3.2.1 Objectives. The objectives of this phase are:

1. Evaluate G&N compatibility with other systems and man in the loop for entry from an orbital mission

2. Evaluate the ability of the pilot subject to arrest tumbling and to reorient the Command Module to proper entry attitude, using updated displays

3. Analyze the failure effects and capability of the pilot subject to identify and manually override G&N commands, when required, to ensure proper Command Module orientation during entry

4. Determine RCS propellant consumption after failure effects, requiring manual overriding by the astronaut

5. Evaluate EMD-SCS-RCS compatibility and investigate the problem areas resulting from the Phase I centrifuge study conducted at Johnsville

6. Define operational procedures for going into and out of G&N manual steering mode

7. Determine failure detection cues for the G&N manual steering concept

8. Evaluate the revised entry display scan pattern, including the degradation in the monitoring of the EMS

9. Investigate the existing concept for manual G&N steering in which the pilot subject disables the roll channel and controls direct to the jets

10. Familiarize NASA astronauts with the entry simulation systems and objectives. Provide capability for astronaut evaluation of the entry flight systems and modes, including the manual G&N steering concept

11. Evaluate the EMS lift vector needle and FDAI "bug" directional movement compatibility

12. Validate task analysis for correct sequence of tasks

13. Evaluate task loading.

10.3.1.3.2.2 Test Plan.

10.3.1.3.2.2.1 Tasks. The tasks to be performed are:

1. Monitor the displays and controls during the entry phase
2. Activate the emergency manual override if contingency requires.

10.3.1.3.2.2.2 Variables. The variables are:

1. Different entry angles
2. Contingencies
3. Shirt sleeve versus pressure garment assembly
4. Orientation by internal versus external displays.

10.3.1.3.2.2.3 Measurements. The measurements to be made include:

1. Computed maximum G's
2. Computed G — onset
3. Computed G — duration at different levels
4. Reaction time
5. Recorded history of G.V. display
6. Tracing of roll position at all times
7. Total fuel consumption
8. Manual attitude control accuracy
9. Time to properly orient Command Module while tumbling
10. Accuracy of task analysis procedures.

10.3.1.3.2.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle E-1
2. Roll indicator
3. FDAI
4. Rate needles
5. Rotational controller
6. Closed-circuit TV
7. X-Y plotter
8. Analog and digital computers with converters
9. 15- to 20-channel pen recorder
10. Pressure garment assembly.

10.3.1.3.2.4 Facilities: Evaluator 1, S&ID, Downey

10.3.1.3.2.5 Test Schedule: May through August 1964 (Figure 10-16)

10.3.1.3.3 Entry Simulation Study 3. (The simulation of a supercircular entry, evaluating the entry monitor display (EMD) in the automatic and manual mode, with man in the loop.) EN-3

10.3.1.3.3.1 Objectives. The objectives of this phase are:

1. Determine the ability of the pilot subject to monitor a primary guidance entry, using the EMD, and to accomplish manual override, if required
2. Evaluate redundancy and backup systems used by the pilot subject during entry, with a primary system malfunction requiring manual override
3. Establish standardized procedures for maneuvering the Command Module in the atmosphere, following a pre-entry failure of the G&N system

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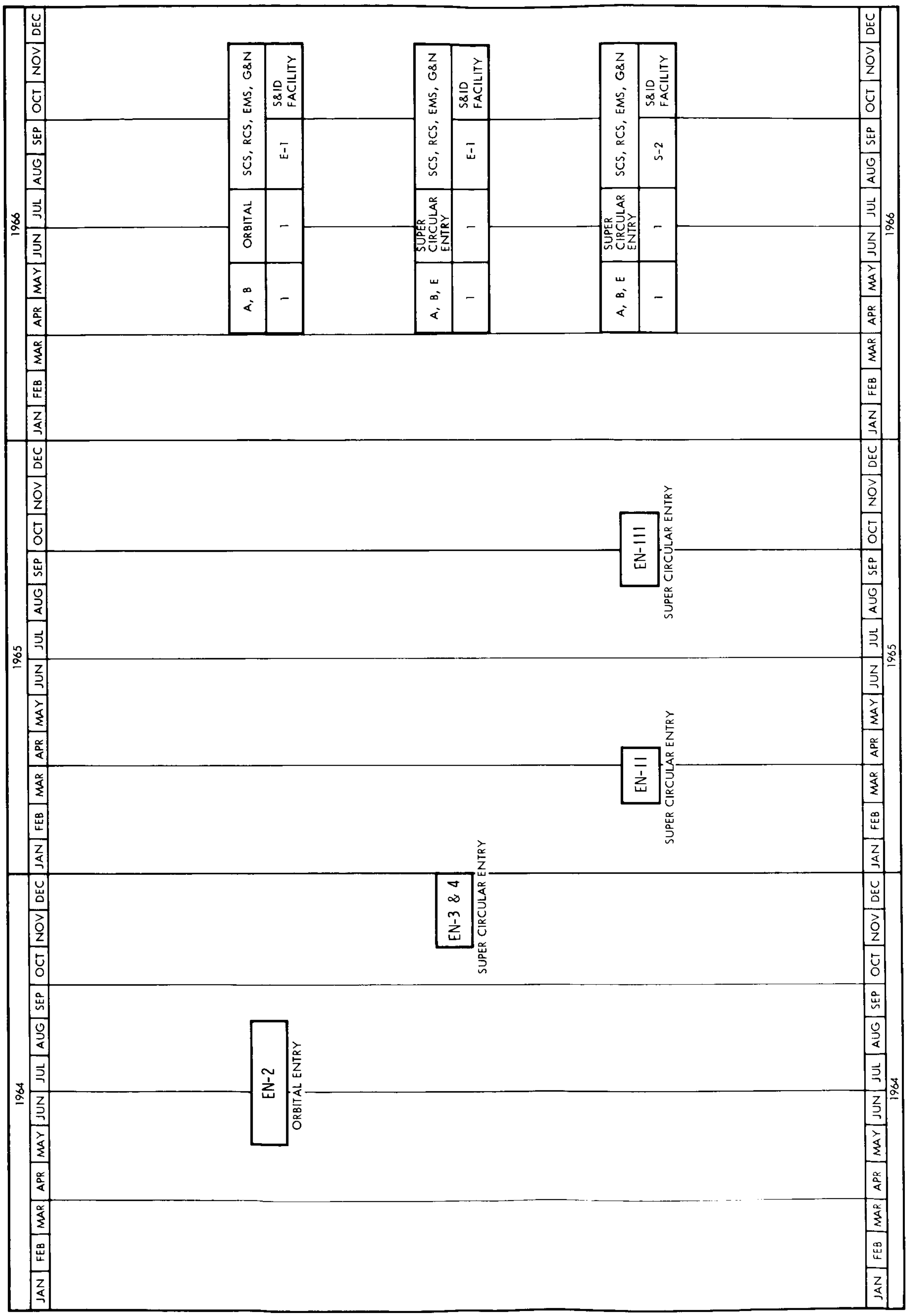

Figure 10-16. Mission Phases Entry Test Schedule

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4. Evaluate the ability of the pilot subject to orient the Command Module for proper re-entry attitude after a successful exit maneuver, with the aid of updated internal and external visual displays

5. Validate task analysis for correct sequence of tasks

6. Investigate the ability of the pilot to extend the downrange landing site by execution of an exit maneuver under manual control

7. Evaluate task loading.

10.3.1.3.3.2 Test Plan.

10.3.1.3.3.2.1 Tasks. The tasks to be performed are:

1. Monitor the displays and controls during the entry phase

2. Activate the emergency manual override if contingency requires.

10.3.1.3.3.2.2 Variables. The variables are:

1. Different entry angles

2. Contingencies

3. Shirt sleeve versus pressure garment assembly

4. Internal and external visual displays.

10.3.1.3.3.2.3 Measurements. The measurements to be made include:

1. Computed maximum G's

2. Computed G — onset

3. Computed G — duration at different levels

4. Reaction time to contingencies

5. Recorded history of G.V. display

6. Tracing of roll position at all times

7. Total fuel consumption

8. Manual attitude control accuracy

9. Downrange landing site accuracy

10. Accuracy of task analysis procedures.

10.3.1.3.3.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle E-1

2. Roll indicator

3. FDAI

4. Rate needles

5. Rotational controller

6. G.V. prototype display

7. Closed-circuit TV

8. Analog and digital computers with converters

9. 15- to 20-channel pen recorders.

10.3.1.3.3.4 Facilities: Evaluator 1, S&ID, Downey

10.3.1.3.3.5 Test Schedule: November and December 1964

10.3.1.3.4 Entry Simulation Study 4. (A simulation for evaluating the overall system performance compatibility of the major systems — G&N, SCS, RCS, EMD — with the crew, task allocations, displays and controls, and the interaction of systems under automatic and manual modes during a supercircular pre-entry and entry mission phase.) EN-4

10.3.1.3.4.1 Objectives. The objectives of this phase are:

1. Evaluate crew performance on integrated tasks such as verifying navigation fixes, ΔV corrections, and FDAI and IMU alignments prior to entry

2. Evaluate operator procedures and validate the task analysis for all pre-entry operations

3. Examine interrelationship of tasks, with specific emphasis on work load task allocations and displays and controls under emergency conditions for pre-entry and entry

4. Evaluate compatibility of the major entry flight systems (G&N, SCS, RCS, EMD) and the astronaut during automatic and manual operations of a supercircular pre-entry and entry mission phase

5. Evaluate the ability of the pilot to accomplish three-axis orientation of the Command Module during exo-atmospheric maneuvers and roll-axis orientation of the Command Module during atmospheric maneuvers, using internal and external visual cues

6. Validate task analysis for correct sequence of tasks.

10.3.1.3.4.2 Test Plan.

10.3.1.3.4.2.1 Tasks. The tasks to be performed are:

1. Take navigational sightings and make ΔV corrections as an integrated crew task

2. Perform FDAI and IMU alignment as an integrated task

3. Maintain crew communications with MDSS

4. Orient high-gain antennas

5. Monitor displays and controls during entry while on automatic mode unless a contingency requires activating the emergency manual override.

10.3.1.3.4.2.2 Variables. The variables are:

1. Task allocations

2. Variable star field

3. Control and display arrangement

4. Different entry angles

5. Contingencies

6. Internal and external visual cues

7. Shirt sleeve versus pressure garment assembly.

10.3.1.3.4.2.3 Measurements. The measurements to be made include:

1. Time period required to perform integrated tasks such as:

   a. Navigational fixes

   b. FDAI and IMU alignment

2. Computed maximum G's

3. Computed G – onset

4. Computed G-duration at different levels

5. Reaction time to contingencies

6. Recorded EMD history of G versus V display

7. Tracing of roll position at all times

8. Total fuel consumption

9. Manual attitude control accuracy

10. Accuracy of task analysis procedures.

10.3.1.3.4.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle – Evaluator 1

2. Analog computer

3. Digital computer

4. A/D and D/A converter

5. TV cameras
6. Monitors (TV)
7. G versus V prototype display
8. X-Y plotter
9. Roll indicator
10. Three caution lights (0.05 G, 0-degree lift, 180-degree lift)
11. FDAI and rate indicators
12. Rotational controller
13. 15- to 20-channel pen recorder
14. Aural 0.05 G indicator
15. SCS control panel
16. IMU control panel
17. Gyro torque control panel
18. Mode select and adjust panel
19. G&N panel with associated SXT and telescope
20. Altimeter
21. Fuel indicator
22. RCS
23. EMD
24. G&N
25. Pressure garments and associated equipment
26. External displays for visual orientation (near earth, far moon, starfield).

10.3.1.3.4.4 Facilities: Evaluator 1, S&ID, Downey

10.3.1.3.4.5 Test Schedule: November and December 1964

10.3.1.3.6 Entry Simulation Study II. (A manned simulation to evaluate Airframe 011 prototype flight hardware compatibility, to confirm previous entry simulation study results, and to re-evaluate potential problem areas identified in previous simulations with man in the loop.) EN-II

10.3.1.3.6.1 Objectives. The objectives of this phase are:

1. Provide a thorough dynamic check and evaluation of prototype flight hardware from a crew systems point of view with a man in the loop environment

2. Confirm previous Airframe 011 manned entry simulation study results

3. Re-evaluate potential problem areas identified in previous simulations

4. Investigate the effects of hardware, G&N characteristics, and man in the loop interaction on overall system performance during entry

5. Confirm crew capability to perform all required tasks during orbital entry

6. Validate task analysis for correct sequence of tasks

7. Evaluate task loading.

10.3.1.3.6.2 Test Plan.

10.3.1.3.6.2.1 Tasks. The tasks to be performed are:

1. Monitor the displays and controls during entry phase

2. Activate the emergency manual override if contingency requires.

10.3.1.3.6.2.2 Variables. The variables are:

1. Different entry angles

2. Contingencies

3. Shirt sleeve versus pressure garment assembly

4. Internal and external visual displays.

10.3.1.3.6.2.3 Measurements. The measurements to be made include:

1. Computed maximum G's

2. Computed G — onset

3. Computed G — duration at different angles

4. Reaction time

5. Amount of time trace is tangent to or greater than tangent to the radial lines on the display

6. Tracing of roll position at all times

7. Total fuel consumption

8. Manual attitude control accuracy

9. Accuracy of task analysis procedures.

10.3.1.3.6.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle — Simulator 2

2. Analog computer

3. Digital computer

4. A/D and D/A converters

5. TV camera

6. Monitor (TV)

7. Rotational controller

8. 15- to 20-channel per recorder

[redacted]

9. Aural 0.05G indicator

10. SCS prototype hardware

11. RCS prototype hardware

12. EMD prototype displays

13. IMU control panel

14. Gyro torque control panel

15. Mode select and adjust panel

10.3.1.3.6.4 Facilities: Simulator 2, S&ID, Downey

10.3.1.3.6.5 Test Schedule: March and April 1965

10.3.1.3.7 Entry Simulation III. (A manned entry simulation to assure hardware compatibility and to evaluate all entry flight systems under simulated supercircular entry conditions to determine any required design changes necessary for crew performance.) EN-III

10.3.1.3.7.1 Objectives. The objectives of this phase are:

1. Provide a thorough dynamic check and evaluation of prototype hardware, with man in the loop

2. Investigate effects of G&N hardware characteristics on overall systems performance during supercircular entry, with man in the loop

3. Verify crew capability to perform all operational tasks during supercircular entry

4. Verify previous simulation study results

5. Re-evaluate potential problem areas identified in previous simulations, with man in the loop

6. Validate task analysis for correct sequence of tasks

7. Evaluate task loading.

10.3.1.3.7.2 Test Plan.

10.3.1.3.7.2.1 Tasks. The tasks to be performed are:

1. Monitor the displays and controls during the entry phase

2. Activate the emergency manual mode if contingency requires.

10.3.1.3.7.2.2 Variables. The variables are:

1. Different entry angles

2. Contingencies

3. Shirt sleeve versus pressure garment assembly

4. Internal and external visual cues.

10.3.1.3.7.2.3 Measurements. The measurements to be made include:

1. Computed maximum G's

2. Computed G — onset

3. Computed G — duration at different angles

4. Reaction time to contingencies

5. Amount of time trace is tangent to or greater than tangent to the radial lines on the display

6. Tracing of the roll position at all times

7. Total fuel consumption

8. Accuracy of task analysis procedures.

10.3.1.3.7.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle — Simulator 2

2. Analog computer

3. Digital computer
4. A/D and D/A converters
5. TV camera
6. Monitor (TV)
7. G. V. prototype display
8. Roll indicator
9. Three caution lights (0.05G, 0-degree lift, 180-degree lift)
10. FDAI and rate indicators (prototype)
11. Rotational hand controller
12. 15- to 20-channel pen recorder
13. Aural 0.05G indicator
14. SCS panel (prototype)
15. IMU control panel (prototype)
16. Gyro torque control panel (prototype)
17. Mode select and adjust panel (prototype)
18. Altimeter (prototype)
19. Fuel indicator (prototype)
20. RCS (prototype)
21. EMD (prototype)
22. G&N (prototype)
23. Pressure garment assembly and associated equipment (prototype).

10.3.1.3.7.4 Facilities: Simulator 2, S&ID, Downey

10.3.1.3.7.5 Test Schedule: September and October 1965

10.3.1.4 Transposition and Docking

10.3.1.4.1 Transposition and Docking. (Evaluation of procedures and equipment required to perform transposition and emergency lunar orbital docking.)

10.3.1.4.1.1 Objectives. The objectives of this phase are:

1. Determine the accuracy range attainable in position and alignment at contact
2. Determine the accuracy range attainable in control of translation rates
3. Develop optimum techniques and procedures for performing transposition and docking (nominal versus backup)
4. Determine the location and type of visual alignment aids, instruments, and lighting required
5. Determine the effects of control modes, control contingencies, and spacecraft dynamics
6. Validate task analysis for correct sequence of tasks
7. Evaluate task loading
8. For Docking I, II, and III, validate task analysis for crew integration compatibility. For the emergency condition, there will be only a one-man crew.

10.3.1.4.1.2 Test Plan.

10.3.1.4.1.2.1 Tasks. Using the SCS, visual aids, and instruments, the tasks to be performed include:

1. Transposition docking
2. Emergency docking.

10.3.1.4.1.2.2 Variables. The variables are:

1. Control systems, attitude hold (rate proportional command) versus direct command (full on/off thrust)
2. Thrust plane position

3. Alignment and positioning aids

4. Limit cycle rates

5. SCS quad failures (single versus asymmetric)

6. Pressure garment assembly operation

7. Exterior lighting

8. Control stick characteristics

9. Docking mechanical systems

10. Fuel and time measurements.

10.3.1.4.1.2.3 Measurements. The measurements to be made include:

1. Position at contact

2. Attitude alignment at contact

3. Propellant consumption

4. Rate of closure at contact

5. Linear velocity at contact

6. Time required for the maneuver

7. Accuracy of task analysis procedures.

10.3.1.4.1.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle: Phase I, Docking A, B, C, and 1 — Columbus simulation laboratory facilities; Docking I and II — Evaluator 2 or Simulator 1

2. Command Module Interior:

   a. Latest Apollo design instrument panel

   b. Latest Apollo design attitude and translational controller

c. Pressure garment assembly (Class III), including provisions for vent air

d. Command Module communications systems.

3. Special equipment:

a. Gimballed starfield

b. LEM and S-IV-B models

c. Position and alignment aids

d. Closed-circuit TV system

e. Jet logic display for observer use.

4. Computers: Analog and Digital

10.3.1.4.1.4 Facilities: Location — Columbus Division

10.3.1.4.1.5 Test Schedule (Figure 10-17):

Phase I, Feasibility	—	October and November 1962 (completed)
Docking A, Parameters	—	May and June 1963 (completed)
Docking B, Parameters	—	December and January 1963-64 (completed)
Docking C, Specification	—	May and June 1964
Docking I, Evaluation	—	August, September, October 1964
Docking I, Verification	—	May and June 1965
Docking II, Verification	—	February and March 1966

10.3.1.5 Rendezvous

10.3.1.5.1 Emergency Rendezvous. Examination of procedures required to perform a successful one-man emergency rendezvous, with the Apollo spacecraft providing the active propulsion. R 1 and 2

10.3.1.5.1.1 Objectives. The objectives of this phase are:

1. Determine pilot subject perception of relative motion between the two vehicles

[redacted]

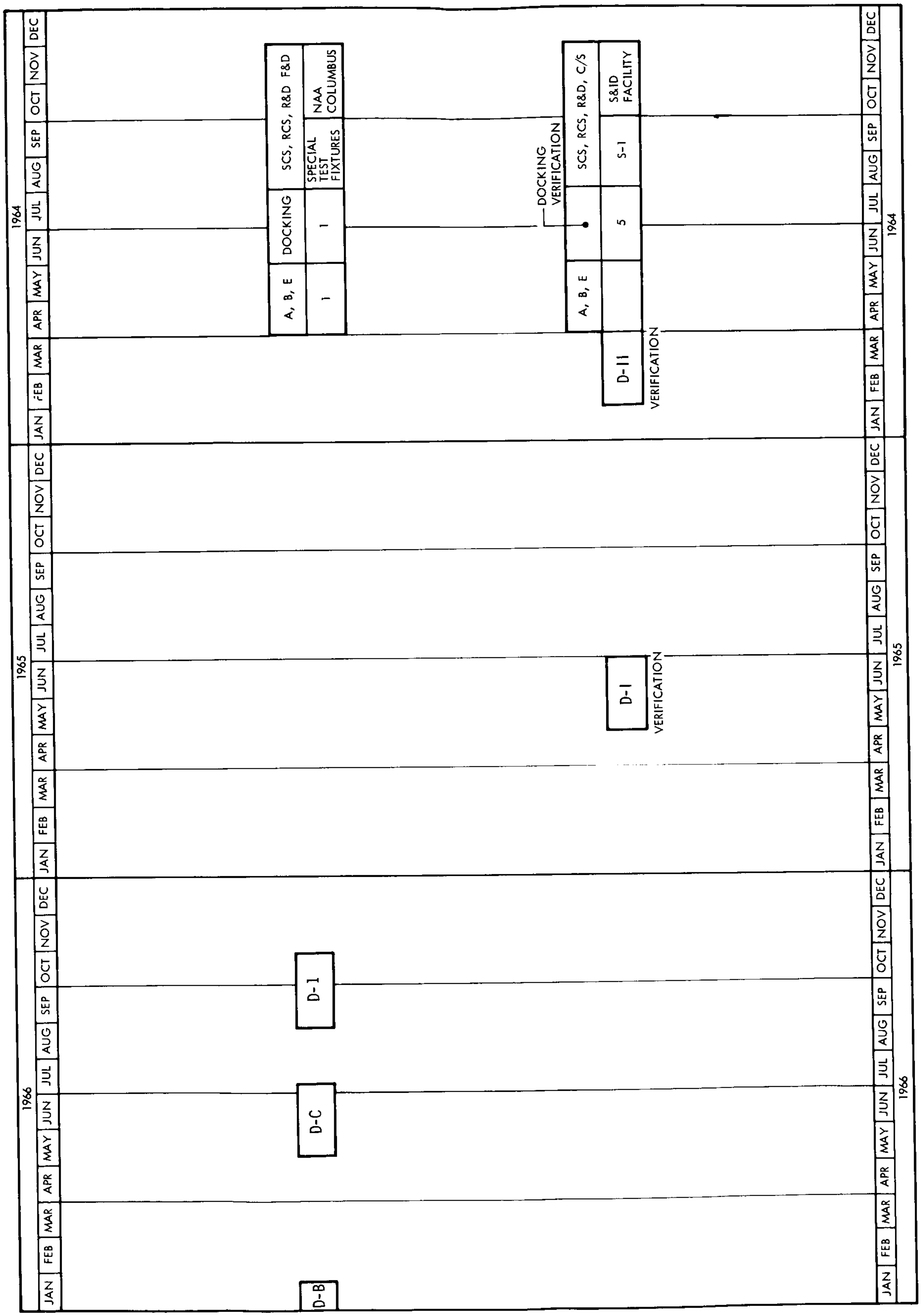

Figure 10-17. Mission Phases Docking Test Schedule

[redacted]

2. Pilot subject ability to correct for relative motion

3. Determine pilot subject ability to make necessary initial ΔV and midcourse corrections required for an orbital transfer

4. Determine optimum location and type of sighting aids required to initiate and complete an emergency rendezvous

5. Determine internal displays necessary to aid in accomplishing emergency rendezvous

6. Explore possible communication procedures to assist in emergency rendezvous

7. Validate task analysis for correct sequence of tasks

8. Evaluate task loading.

10.3.1.5.1.2 Test Plan.

10.3.1.5.1.2.1 Tasks. The task to be performed is complete emergency rendezvous utilizing the SPS, RCS, displays and controls, and visual aids as required.

10.3.1.5.1.2.2 Variables. The variables are:

1. Locations and positioning of various sighting aids

2. Emergency rendezvous profiles

3. Identification light on target vehicle

4. Lighting variations

5. Initial conditions

6. Various radar instrument displays

7. Various locations of scanning telescope (SCT) used to locate target and align radar antenna

[redacted]

8. LEM abort trajectories

9. Various Command Module systems failures

10.3.1.5.1.2.3 Measurements. The measurements to be made include:

1. Pilot subject ability to correct relative motion

2. Accuracy of orbit-to-orbit transfer

3. Attitude errors

4. Final position errors

5. RCS fuel expended for orbital transfer midcourse corrections

6. SPS fuel expended during ΔV required for orbital transfer

7. Accuracy of task analysis procedures.

10.3.1.5.1.3 Equipment Requirements. The equipment required is as follows:

1. Vehicles: Evaluator 2 and Simulator 1

2. Command Module interior:

    a. Latest Apollo rotational and translational controllers

    b. Pressure garment assembly including provisions for vent air

    c. Command module communications system

    d. Latest Apollo design instrument panel with the following systems active:

        (1) SCS, including FDAI (Command Module)

        (2) RCS

[redacted]

(3) ΔV - TVC

(4) Radar electronics and displays

3. Special equipment:

   a. Gimballed starfield

   b. External visual aids (gunsights, reticle and simulated LEM with lights)

   c. Closed circuit Television

   d. Lunar surface

   e. Lighting equipment

   f. Special LEM models and/or lights

4. Computers: analog and digital computer complex.

10.3.1.5.1.4 Facilities. Evaluator 2 and Simulator 1, S&ID, Downey

10.3.1.5.1.5 Test Schedule. (Figure 10-18)

1. Rendezvous Study No. 1 and 2. Instrument controlled versus visual rendezvous, December 1964

2. Rendezvous Study No. 3. Backup rendezvous subsystems design requirements evaluation to run, June 1965

3. Rendezvous Study No. 4. Earth Orbital rendezvous system design evaluation, July 1966 (E-2)

4. Rendezvous Study No. I. CSM rendezvous subsystem hardware compability evaluation to run, December 1965 and January 1966 (S-1).

[redacted]

[redacted]

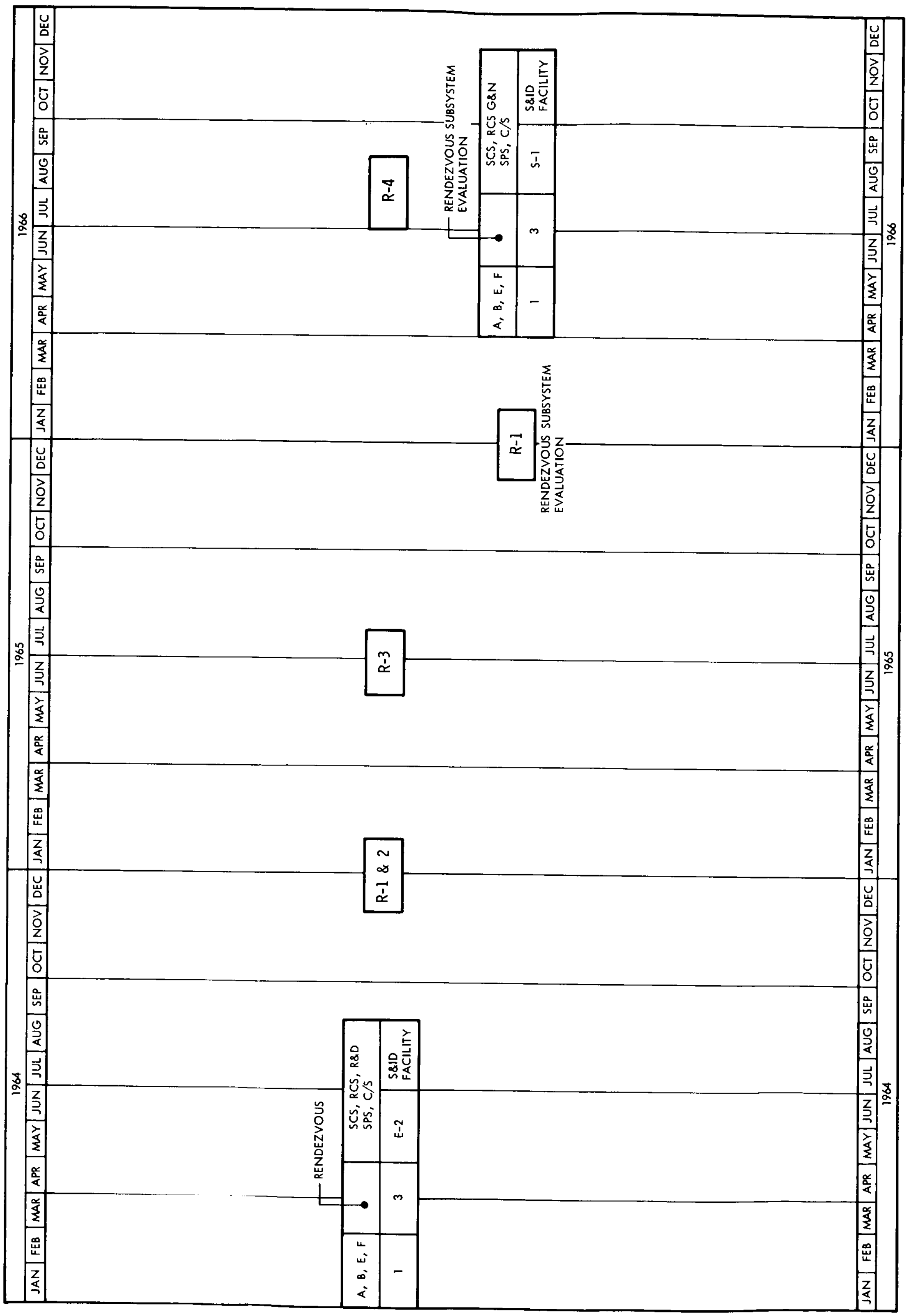

Figure 10-18. Mission Phases Rendezvous

[redacted]

10.3.2 Dynamic Base

10.3.2.1 Manned Centrifuge Study, Phase I

(Evaluation of Apollo design parameters by assessment of crew performance during launch, abort, and entry acceleration.) Dy-2 (completed)

10.3.2.1.1 Objectives. The objectives of this phase are:

1. Investigate interface problems under Apollo acceleration loads (couch-harness-suit-man)

2. Evaluate current Apollo design parameters (control-display adequacy)

3. Determination of acceleration profile acceptability

4. Evaluate pilot performance in manual override modes.

10.3.2.1.2 Test Plan.

10.3.2.1.2.1 Tasks. The tasks to be performed are:

1. Monitor systems during launch

2. Initiate pad, maximum Q, and high altitude abort

3. Perform manual overrides on LES

4. Perform manual overrides on ELS

5. Perform manual mode entry tracking.

10.3.2.1.2.2 Variables. The variables are:

1. Worst case entry profiles

2. Subjects (Six NASA furnished astronauts)

3. Various abort profiles (pad, maximum Q, high altitude)

4. Crew couch adjustments.

10.3.2.1.2.3 Measurements. The measurements to be performed include:

1. Ability and time required to initiate manual abort
2. Efficiency of manual overrides during acceleration profiles
3. Accuracy of entry tracking (manual mode)
4. Monitoring efficiency (errors and time)
5. Physiological parameters
6. Crew couch and restraint characteristics.

10.3.2.1.3 Equipment Requirements. NAA furnished test fixture is to be installed in the Johnsville AMAL centrifuge gondola. The fixture contains framework, instrument panel, hand controllers, couch and restraint system, as well as NASA furnished ventilation system, pressure garment assembly (Class III), biomedical monitoring instrumentation, and monitoring TV camera.

10.3.2.1.4 Facilities. The facilities required are:

1. Johnsville AMAL, NADC centrifuge, driving computers, and recorders
2. G profiles furnished by NAA
3. Fixture furnished by NAA
4. Computer mechanization furnished by NAA.

10.3.2.1.5 Schedule (Figure 10-19). The schedule for this phase is as follows:

1. Begin Johnsville installation 1 October 1963
2. Begin data runs 28 October 1963 (completed).

10.3.2.2 Centrifuge, Phase II

(Simulation and evaluation of displays and controls necessary under acceleration and vibration profiles.) Dy-3 Design Verification.

[redacted]

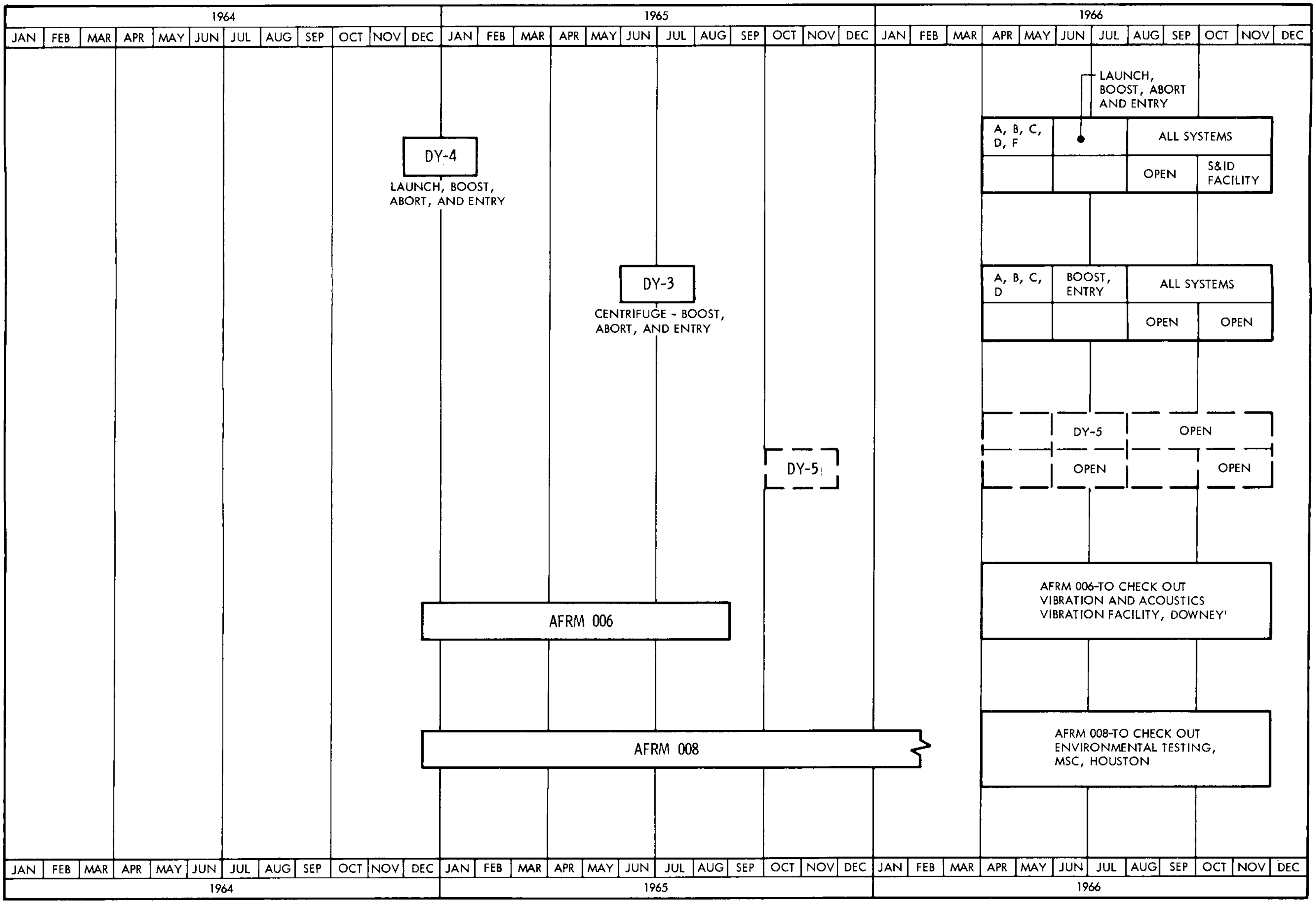

Figure 10-19. Dynamic Base Test Schedule

[redacted]

[redacted]

10.3.2.2.1 Objectives. The objectives of this phase are as follows:

10.3.2.2.1.1 Design Verification of Crew Equipment and Related Hardware During Acceleration Environment. Of particular concern is the interface between the pressure garment, restraint harness, and couch. Pressure points, support adequacy, flexibility, compatibility, mobility, control interference, and visual integration are parameters to be measured.

10.3.2.2.1.2 Design Verification of Control and Display Hardware. The design of all controls and displays pertinent to entry and boost-abort will be verified. Of primary concern are those at the commander's station including the main display panel, particularly SCS control and mode select panel, EDS, caution-warning system, crew safety control panel and ELS; rotation control; translation control; EMS; FDAI; and the G&N panel.

10.3.2.2.1.3 Determination of Acceptability of Apollo Acceleration Profiles. Various abort conditions and various entry conditions as well as ranging requirements will be introduced. Both performance and physiological criteria will be used to assess the acceptability of acceleration profiles of boost-abort and entry.

10.3.2.2.1.4 Verification of Operational Procedures. Pilot functions during entry, which will require verification, include G&N monitor and override procedures, G&N manual steering, SCS entry mode steering, and recognition and correction of simulated flight control systems malfunctions. Boost-abort procedures including contingency recognition and switching functions will also be studied. Operational procedures for the navigator and the systems engineer will also be confirmed should multi-man testing be required.

10.3.2.2.1.5 Confirmation of Fixed Base Man-in-the-Loop Results. Pertinent results of entry, boost-abort, and crew hardware interfaces obtained in static simulation will be explored as a function of acceleration.

10.3.2.2.2 Test Plan.

10.3.2.2.2.1 Tasks. The tasks to be performed are:

1. Monitor the emergency detection system (EDS), FDAI, EMS, LES, caution lights, warning lights and abort light and make appropriate responses

2. Maintain MDSS communications

[redacted]

3. Initiate proper abort sequence depending on contingency with the translation control

4. Perform adequate entry maneuvers and ranging requirements during entry using EMS, FDAI, and SCS systems and the rotation control.

10.3.2.2.2.2 Variables. The variables are:

1. Automatic versus manual versus manual backup aborts

2. Pressure garment assembly (Class III) pressurized versus non-pressurized

3. Go versus no-go instrument indications

4. Vibration versus environment

5. Atmospheric environment

6. Representative entry conditions

7. Type of contingency situation.

10.3.2.2.2.3 Measurements. The measurements to be made include:

1. Time required to detect and react to possible abort situation

2. Time required for abort decision making

3. Accuracy of closed-loop entry maneuvers (takeover and ranging)

4. Physiological data

5. Accuracy of decisions regarding manual override (abort or entry takeover)

6. Efficiency of entry maneuvers (RCS duty cycles and propellant consumption)

7. Accuracy of task analysis procedures.

10.3.2.2.3 Equipment Requirements. The equipment required is as follows:

1. Special test fixture
2. Crew couch and restraints
3. Pressure garment assembly (Class III)
4. Biomedical instrumentation
5. Motion picture and television cameras
6. The entire main display console
7. Rotation control
8. Translation control
9. ECS
10. Command module communications systems
11. IC stop button
12. Computers (As specified in SID 62-1303, 1.5; 2.31; 4.5; 5.0 and as available at the selected centrifuge facility.

10.3.2.2.4 Facilities. Centrifuge at NADC-AMAL, NASA-MSC or NASA-ARC

10.3.2.2.5 Test Schedule. June and July 1965

10.3.2.4 Vibration and Noise Level Crew Effects Tests

(Evaluate abilities of crew related to monitoring and manual override duties.) Dy-4

10.3.2.4.1 Objectives. The objectives of this phase are:

1. Evaluate crew performance decrements and task loading in monitoring required during launch, abort and entry oscillation

2. Evaluate ability of crew to initiate abort during boost oscillations within design limits

3. Evaluate task loading and capability of crew to perform all necessary manual overrides during post-abort oscillations

4. Evaluate ability of crew to perform required entry maneuvers

5. Determine adequacy of speech intelligibility in crew communications during launch and entry oscillation periods

6. Assess crew support system to assure satisfactory vibration isolation.

10.3.2.4.2 Test Plan.

10.3.2.4.2.1 Tasks. The tasks to be performed are:

1. Monitor displays during launch oscillation

2. Initiate abort if required

3. Perform all manual LES and ELS overrides following abort vibration

4. Perform manual mode entry during oscillation

5. Communicate with simulated MDSS during all mission vibration profiles.

10.3.2.4.2.2 Variables. The variables are:

1. Command module dynamic vibration equations for launch, abort and entry

2. Intensity of vibration levels

3. Pressurized versus unpressurized suit conditions.

10.3.2.4.2.3 Measurements. The measurements to be made include:

1. Visual perception of display information during launch, abort, and entry vibration

[redacted]

2. Ability of crew to initiate abort during launch oscillation within design limits

3. Accuracy of switching function

4. Accuracy of entry maneuvers

5. Intelligibility of crew verbal transmissions

6. Vibration intensity levels recorded by accelerometers placed on crew members.

10.3.2.4.3 Equipment Requirements. The equipment required is as follows:

1. Vehicles: A special test fixture incorporating a complete spacecraft crew support system and vibration-proof panel will be utilized. The fixture will be rigidly mounted on a shake table and driven in three axes (X, Y and Z).

2. Displays - Controls:

   a. Hand controls on couch arms

   b. Display panel complete with major displays (ELS, LES, EDS, event timer, SCS, RCS, EMS, PUCS, etc.)

   c. Communications

3. Computers: Analog computer tie-in.

10.3.2.4.4 Facilities. S&ID, Downey, or LAD, Los Angeles

10.3.2.4.5 Test Schedule. December 1964 and January 1965

10.3.2.5 Spacecraft Tumbling Simulation

(Stabilization of command module during tumbling induced by mission abort, i.e., pad abort, maximum Q abort and high altitude abort using command module RCS manual and automatic modes.) Dy-5. (This test will be conducted only if boilerplate shots indicate excessive torque is induced in command module on abort.)

10.3.2.5.1 Objectives. The objectives of this phase are:

1. Evaluate crew couch and restraint systems under various tumbling situations
2. Evaluate crew ability to stabilize command module when tumbling using emergency manual mode of SCS
3. Evaluate crew performance and task loading using various displays and external visual cues required to stabilize tumbling and assume entry attitude
4. Evaluate task loading and crew ability to maintain proper entry attitude after stabilization from tumbling.

10.3.2.5.2 Test Plan.

10.3.2.5.2.1 Tasks. The tasks to be performed are:

1. Null a combination of simultaneous pitch, yaw, and roll rates
2. Reorient command module to entry angle

10.3.2.5.2.2 Variables. The variables are:

1. Various mission phase aborts
2. Various tumbling torque rates
3. Various crew restraint systems
4. Various cues for command module orientation
5. Manual versus automatic stabilization

10.3.2.5.2.3 Measurements. The measurements to be made include:

1. Effectiveness of crew restraint system with respect to affording the crew ample protection and freedom of hand and head movements required to control the command module
2. Roll, pitch and yaw position with respect to desired positions and initial rates

3. Integrated yaw, pitch and roll errors of absolute position from desired position to 2-degree deadband

4. Time to dampen tumbling

5. Time to reorient to entry angle.

10.3.2.5.3 Equipment Requirements. The equipment required is as follows:

1. Command module interior

    a. Latest Apollo design controls and displays

    b. MDSS communications

    c. Pressure garment assembly (Class III)

    d. Crew couches and restraint systems

    e. Motion picture and television cameras

2. Simulated earth horizon

3. Vehicle - special test fixture.

10.3.2.5.4 Facilities. To be determined

10.3.2.5.5 Test Schedule. To be determined

10.3.3 Qualification Testing

Support for qualification testing on AFRM 008 and AFRM 006 will be provided as required. It is expected that participation will consist of the scheduling and conducting of the portions of the testing which require flight control qualified subject participation.

10.3.4 Systems Integration

10.3.4.1 Critical Mission Phases - Systems Integration

(Examination of interrelationship of tasks, with specific emphasis on work load, and task allocation) In-2

10.3.4.1.1 Objectives. The objectives of this phase are:

1. Validate task analysis for correct sequence of tasks

2. Determine potential task overloadings

3. Evaluate the effects of equipment design and functional arrangements on the performance of crew integrated tasks.

10.3.4.1.2 Test Plan.

10.3.4.1.2.1 Tasks. (Performed as an integrated crew) The tasks to be performed are:

1. Make navigational sightings and ΔV maneuvers

2. Perform transposition and docking

3. Align FDAI and IMU

4. Perform pre-launch and launch procedures

5. Perform entry maneuver

6. Perform necessary MDSS communication and consultation during critical mission phases

7. Monitor and communicate system verifications among crew members and with MDSS.

10.3.4.1.2.2 Variables. The variables are:

1. Task allocation

2. Variable star field

3. Pressure garment assembly versus shirt sleeve.

10.3.4.1.2.3 Measurements. The measurements to be made include:

1. Accuracy of task analysis procedures

2. Ease with which integrated tasks are performed

3. Time required to perform integrated tasks.

[redacted]

10.3.4.1.3 Equipment Requirements. The equipment required is as follows:

1. Command module interior: Latest Apollo design - displays and controls (hardware checkout)

2. External simulated MDSS and LEM communications

3. Computers: Requirements as stated in SID 62-1303, 2.2, 4.1 and 4.2.

10.3.4.1.2.4 Facilities: Vehicle E-2, S&ID, Downey

10.3.4.1.5 Test Schedule. September and October 1964 (Figure 10-20)

10.3.4.2 Systems Integration, One Man Emergency Earth Return

Evaluation of spacecraft design and crew functions during simulated lunar orbit, transearth injection, transearth coast, and entry where one crewmember must carry out the mission alone. In-3

10.3.4.2.1 Objectives. The objectives of this phase are:

1. Evaluate task loading and work-rest schedule during one-man operations, including earth return

2. Validate task analysis for correct sequence of tasks

3. Evaluate cabin interior arrangement during one-man operation, noting modifications which might be made without compromising efficiency of normal three-man operations

4. Assess display and control arrangement for ease of operation by single crewmember

5. Assess food management and personal hygiene procedures under extended duty conditions

6. Evaluate effectiveness of various auditory signals in alerting crewman for duty

7. Demonstrate capability of MDSS to relieve workload (i.e., to monitor spacecraft parameters while crewman is off-duty)

[redacted]

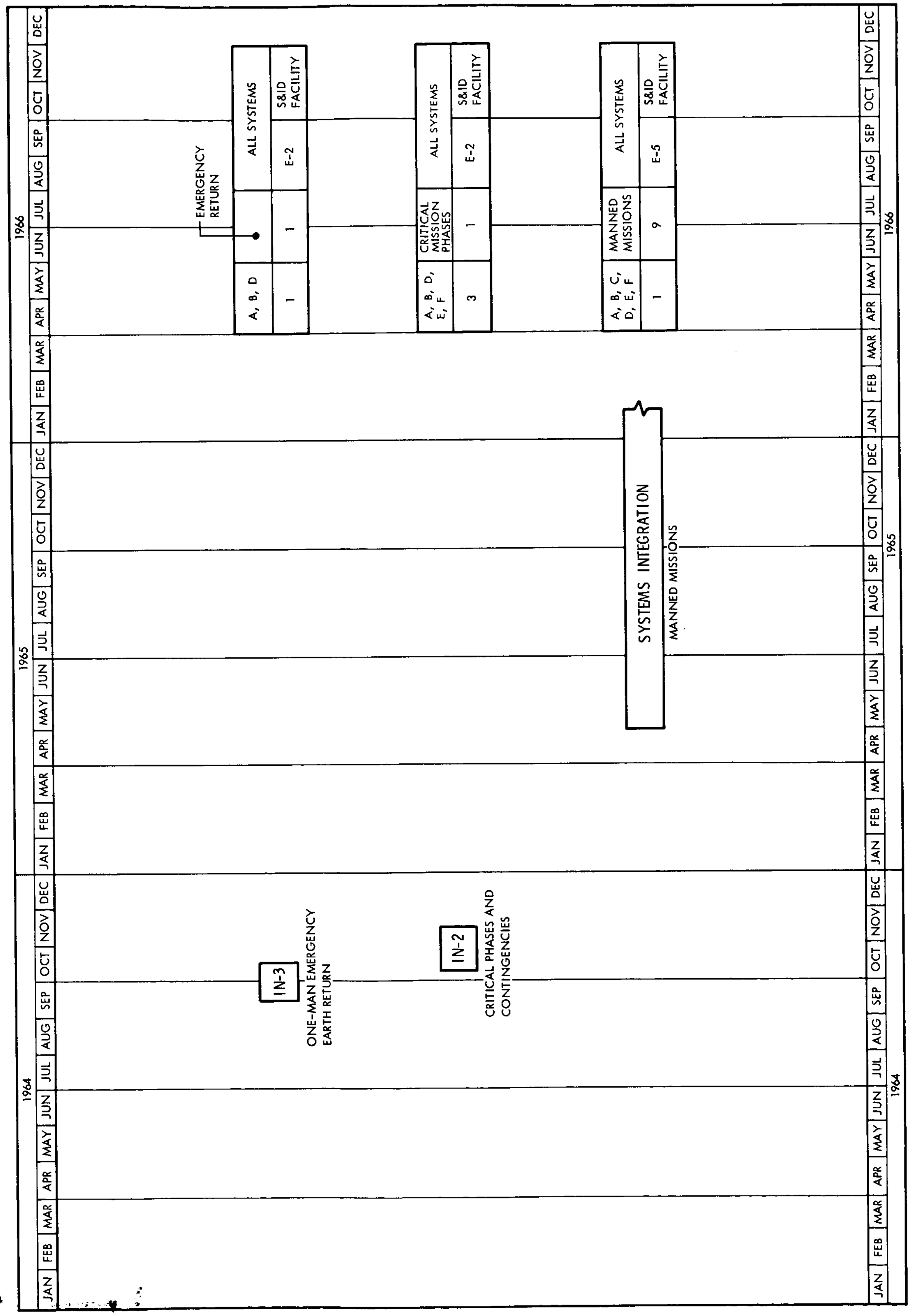

Figure 10-20. Systems Integration Test Schedule

[redacted]

[redacted]

8. Evaluate performance in non-pressurized, ventilated spacesuit.

10.3.4.2.2 <u>Test Plan</u>.

10.3.4.2.2.1 Tasks. The crewman will operate on an irregular duty cycle consonant with the time restrictions accompanying one-man performance of all spacecraft duties. Tasks involving systems operation and checkout, attitude control problems, and monitoring will be simulated in accordance with expected mission parameters. Subjects will fly an entry profile during the last hour of the mission. An Apollo developmental food diet will be provided.

10.3.4.2.2.2 Variables. The variables are:

1. Days
2. Methods of alerting subject for duty
3. Length of duty periods
4. Length of off-duty and sleep periods
5. Command module interior lighting (e.g., changes due to sunshafting)
6. Pressure garment assembly pressurized versus PGA vented.

10.3.4.2.2.3 Measurements. The measurements to be made include:

1. Accuracy and efficiency of general performance and behavior over time
2. Effectiveness of each alerting method
3. Attitude control errors
4. G&N errors
5. Suit inlet and outlet temperatures and relative humidity, inlet flow rate

[redacted]

6. Checklist evaluation of suitability of personal and spacecraft equipment and procedures

7. Accuracy of task analysis procedures.

10.3.4.2.3 Equipment Requirements. The equipment required is as follows:

1. Special equipment: central control console

2. Command module interior

    a. Latest Apollo design display and controls

    b. Simulated guidance and navigation system

    c. Pressure garment assembly including provisions for vent air within test vehicle

    d. Two-way communications for MDSS simulation

    e. Operable entry indicator

    f. TV monitoring equipment

    g. Crew couches

    h. Personal hygiene and medical monitoring equipment

    i. Miscellaneous hardware

3. Computers.

10.3.4.2.4 Facilities. Evaluator 2, S&ID, Downey

10.3.4.2.5 Test Schedule. 80 hour real-time. Three weeks of medical evaluation and task training will precede the test (June 1964).

10.3.4.3 Systems Integration

(Evaluation of in-flight operations during a simulated ten-day earth orbital mission.)

10.3.4.3.1 Objectives. The objectives of this phase are:

1. Evaluate display and control arrangement for ease and efficiency of operation
2. Evaluate task schedule for ten-day earth-orbital mission
3. Determine crew and spacecraft equipment capability in simulated emergency conditions
4. Evaluate performance of orbital navigation tasks
5. Monitor physiological condition of crewmen
6. Evaluate food and waste management and personal hygiene procedures
7. Validate task analysis for correct sequence of tasks
8. Evaluate task loading
9. Validate task analysis for crew integration compatibility.

10.3.4.3.2 Test Plan.

10.3.4.3.2.1 Task. Crewmen will operate under the work-rest schedule and task assignments proposed for the ten-day, earth-orbital mission. Tasks involving systems operation and checkout, navigational problems, attitude control problems, and monitoring and maintenance functions will be programmed in accordance with expected mission parameters. Contingency situations will be simulated for diagnostic and corrective action by the crewmen. Physiological measurements will be made throughout the mission. An Apollo developmental food diet will be provided.

10.3.4.3.2.2 Variables. The variables are:

1. Days
2. Command module interior lighting
3. Pressure garment assembly, pressurized versus non-pressurized versus constant-wear garment.

10.3.4.3.2.3 Measurements. The measurements to be made include:

1. Accuracy and efficiency of performance over a period of time
2. Crewman's ability to detect, evaluate, and correct malfunctions
3. Accuracy of attitude control and re-entry maneuvers
4. Accuracy of G&N sightings
5. Accuracy of task analysis procedures
6. Various physiological measurements.

10.3.4.3.3 Equipment Requirements. The equipment required is as follows:

1. Special equipment - crew systems test console
2. Command module interior
    a. Latest Apollo design displays and controls
    b. Simulated G&N equipment (with visual displays)
    c. Pressure garment assembly and constant-wear garments
    d. Physiological recording
    e. Simulated MDSS
    f. Television monitoring equipment
    g. Crew couches
    h. Life support provisions

10.3.4.3.4 Facility. Evaluator E-5, S&ID, Downey

10.3.4.3.5 Test Schedule. May 1965

10.3.4.4 Systems Integration

Evaluation of in-flight operations during a simulated long duration earth orbital mission.

10.3.4.4.1 Objectives. The objectives of this phase are:

1. Evaluate display and control arrangement for ease and efficiency of operation

2. Evaluate task schedule for long duration earth orbital mission

3. Determine crew and spacecraft equipment capability in simulated emergency conditions

4. Evaluate performance of orbital navigation task

5. Evaluate midcourse navigation task performance

6. Monitor physiological condition of crewmen

7. Evaluate food and waste management and personal hygiene procedures

8. Validate task analysis for correct sequence of tasks

9. Evaluate task loading

10. Validate task analysis for crew integration compatibility.

10.3.4.4.2 Test Plan.

10.3.4.4.2.1 Task. Crewmen will operate under the work-rest schedule and task assignments proposed for a long duration earth orbital mission. Tasks involving systems operation and checkout, navigational problems, attitude control problems, and monitoring and maintenance functions will be programmed in accordance with expected mission parameters. Contingency situations will be simulated for diagnostic and corrective action by the crewmen. Physiological measurements will be made throughout the mission. An Apollo developmental food diet will be provided.

10.3.4.4.2.2 Variables. The variables are:

1. Days

2. Command module interior lighting

3. Pressure garment assembly, pressurized versus non-pressurized versus constant-wear garment.

10.3.4.4.2.3 Measurements. The measurements to be made include:

1. Accuracy and efficiency of performance over a period of time
2. Crewman's ability to detect, evaluate, and correct malfunctions
3. Accuracy of attitude control and re-entry maneuvers
4. Accuracy of G&N sightings
5. Various physiological measurements
6. Accuracy of task analysis procedures.

10.3.4.4.3 Equipment Requirements. The equipment required is as follows:

1. Crew systems test console
2. Command module interior
    a. Latest Apollo design displays and controls
    b. Simulated G&N equipment (with visual displays)
    c. Pressure garment assembly and constant wear garments
    d. Physiological recording equipment
    e. Simulated MDSS capability
    f. Television monitoring equipment
    g. Crew couches
    h. Life support provisions.

10.3.4.4.4 Facility. Evaluator E-5, S&ID, Downey

10.3.4.4.5 Test Schedule. July 1965.

[redacted]

10.3.4.5 Systems Integration

Spacecraft for first manned flight, earth orbital qualification maximum duration. Also, it is the first flight of the Saturn IB vehicle.

10.3.4.5.1 Objectives. The objectives of this phase are:

1. Evaluate display and control arrangement for ease and efficiency of operation
2. Evaluate procedures for monitoring system sequencing and reporting
3. Evaluate detection of simulated failures or malfunctions using the system manager's panel. Determine whether time will allow the crew to obtain the agreement of ground based engineers regarding remedial action to be taken.
4. Evaluate midcourse navigational accuracy and performance
5. Evaluate SPS performance during long duration firing
6. Evaluate SCS closed-loop performance
7. Evaluate launch countdown operations
8. Validate task analysis for correct sequence of tasks
9. Evaluate task loading
10. Validate task analysis for crew integration compatibility.

10.3.4.5.2 Test Plan.

10.3.4.5.2.1 Tasks. The studies will be conducted in a real time situation. The crewman will be inserted at 2.75 hours prior to lift-off. Tasks involving systems operation and checkout, navigational problems, attitude control problems, and monitoring and maintenance functions will be programmed in accordance with expected mission parameters. Contingency situations will be simulated for diagnostic and corrective action by the crewmen. Simulated malfunctions will be of such a nature that the systems manager will make use of the in-flight test system, while simultaneously a second crewman will be taking sightings for orbital determination. A cabin pressurization loss will be simulated by applying a differential pressure to the suit circuit and the mission will be completed in the pressurized state.

10.3.4.5.2.2 Variables. The variables are:

1. Suit pressure differential

2. The number of simulated malfunctions and the compound failure

3. Cabin interior lighting (e.g., changes due to sunshafting)

4. Days.

10.3.4.5.2.3 Measurements. The measurements to be made include:

1. Accuracy and efficiency of general performance with the passage of time

2. Crewmen's ability to detect, evaluate and correct malfunctions

3. Accuracy of attitude control during the entry maneuver

4. Accuracy of G&N sightings

5. Various physiological measurements (i.e., EKG, suit temperature, etc.)

6. Accuracy of task analysis procedures.

10.3.4.5.3 <u>Equipment Requirements</u>. The equipment required is as follows:

1. Special equipment - crew systems test console

2. Command module interior

   a. Latest Apollo design displays and controls

   b. Simulated G&N equipment (with visual displays)

   c. Pressure garment assembly with provisions for vent air within test vehicle, constant-wear garments

   d. Sanborn recorder tie-in for physiological recording

   e. Two-way communications for MDSS simulation

f. Operable entry indicator

g. Television monitoring equipment

h. Crew couches

i. Life support provisions

j. Personal hygiene and medical monitoring equipment.

10.3.4.5.4 Facilities. Vehicle E-5, S&ID, Downey

10.3.4.5.5 Test Schedule. October 1965.

10.3.4.6 Systems Integration

Spacecraft for manned three-orbit elliptical flight. (A manned, three-orbit small elliptical, land or water recovery mission to develop spacecraft systems.)

10.3.4.6.1 Objectives. The objectives of this phase are:

1. Evaluate launch countdown operations
2. Evaluate SPS, G&N, SCS, and RCS performance during re-entry
3. Evaluate SPS performance during long duration firing
4. Evaluate the CSS closed-loop performance
5. Evaluate the performance of the orbital navigation tasks
6. Evaluate the sequence task for completeness and practicality
7. The crewmen will be inserted at T-165 minutes and a simulated or real work load will be imposed on all crew members prior to lift-off
8. Evaluate task loading
9. Validate task analysis for crew integration compatibility.

10.3.4.6.2 Test Plan.

10.3.4.6.2.1 Tasks. Crewmen will operate under the work-rest schedule for the three-orbit mission. Tasks involving systems operation and checkout, navigational problems, attitude control problems, and monitoring and maintenance functions will be programmed in accordance with expected mission parameters. Contingency situations will be simulated for diagnostic and corrective action by the crewmen.

10.3.4.6.2.2 Variables. The variables are:

1. Command module interior lighting
2. Number of failures
3. Pressure garment assembly (pressurized versus nonpressurized)
4. Background noise level change to impose communication difficulties between the crewman.

10.3.4.6.2.3 Measurements. The measurements to be made include:

1. Accuracy and reaction time for corrective actions
2. Accuracy of attitude control during navigational sighting and the profile flown during the entry maneuver
3. Accuracy of G&N sightings
4. Accuracy of task analysis procedures.

10.3.4.6.3 <u>Equipment Requirements</u>. The equipment required is as follows:

1. Special equipment: Crew systems test console
2. Command module interior
    a. Latest Apollo design display and controls
    b. Simulated G&N equipment (with visual displays)
    c. Pressure garment assembly with provisions for vent air within test vehicle, constant-wear garments
    d. Sanborn recorder tie-in for physiological recording
    e. Two-way communications for MDSS simulation

f. Operable entry indicator

g. Television monitoring equipment

h. Crew couches

i. Life support provisions

j. Personal hygiene and medical monitoring equipment.

10.3.4.6.4 Facilities. Vehicle E-5, S&ID, Downey

10.3.4.6.5 Test Schedule. January 1966

10.3.4.7 Systems Integration

A manned earth orbital, land or water recovery mission, to develop LEM spacecraft systems and procedures (unmanned LEM separation, 3 day mission).

10.3.4.7.1 Objectives. The objectives of this phase are:

1. Evaluate crew tasks on an earth orbital mission
2. Determine crew and spacecraft equipment capability in simulated emergency conditions
3. Evaluate crew interactions and performance during systems operation and checkout
4. Evaluate transposition maneuvers in earth orbit
5. Evaluate LEM rescue capability
6. Validate task analysis for correct sequence of tasks
7. Evaluate task loading
8. Validate task analysis for crew integration compatibility.

10.3.4.7.2 Test Plan.

10.3.4.7.2.1 Tasks. The crew will operate under the work-rest and task-analysis schedule for the earth orbital mission. Contingency situations requiring diagnostic and corrective action by the crew will be simulated. The crew will perform a complete transposition and docking task.

10.3.4.7.2.2 Variables. The variables are:

1. Command module interior lighting

2. Target identification lights

3. Pressure garment assembly (pressurized versus unpressurized versus constant-wear garments)

4. External sighting aids for docking.

10.3.4.7.2.3 Measurements. The measurements to be made include:

1. Accuracy and efficiency of general performance over time

2. Total rotational and translational fuel expended

3. Accuracy of final docking positions and rates

4. Accuracy of diagnosis and malfunction correction contingencies

5. Accuracy of G&N sightings

6. Accuracy of attitude control and re-entry maneuver

7. Accuracy of task analysis procedures.

10.3.4.7.3 Equipment Requirements (Command Module interior). The equipment required is as follows:

1. Latest Apollo design displays and controls

2. Simulated G&N equipment (with visual displays)

3. Simulated rendezvous radar controls and displays

4. Pressure garment assembly with provisions for vent air within test vehicle, constant wear garments

5. Closed circuit Television monitoring equipment

6. Life support provisions (personal hygiene, medical care as required)

7. MDSS communications

8. Six DOF LEM model.

10.3.4.7.4 Facilities. Vehicle E-5, S&ID, Downey

10.3.4.7.5 Test Schedule. One year prior to actual mission

10.3.4.8 Systems Integration

Evaluation of in-flight operations including first manned LEM separation during a simulated earth-orbital mission.

10.3.4.8.1 Objectives. The objectives of this phase are:

1. Evaluate crew interactions with LEM displays, controls, and procedures

2. Monitor physiological condition of crew

3. Evaluate LEM navigational task performance

4. Evaluate crew and spacecraft equipment in simulated transposition maneuvers

5. Evaluate LEM/spacecraft/ground communications procedures

6. Validate task analysis for correct sequence of tasks

7. Evaluate task loading during preinjection systems checkout and countdown

8. Validate task analysis for crew integration compatibility.

10.3.4.8.2 Test Plan.

10.3.4.8.2.1 Tasks. Crewman will operate under the work-rest schedule and task assignment proposed for the fourth Saturn 1B manned earth-orbit flight. Tasks involving systems operation and checkout, navigational problems, rescue and emergency situations, transposition and docking maneuvers, and communication techniques will be programmed in accordance with expected mission parameters. Contingencies will be simulated for interpretation and corrective action by the crew.

10.3.4.8.2.2 Variables. The variables are:

1. Lighting variations
2. Pressure garment assembly (pressurized versus nonpressurized versus constant-wear garment)
3. Contingencies
4. Cabin temperature and pressure.

10.3.4.8.2.3 Measurements. The measurements to be made include:

1. Various physiological measurements
2. Error rates
3. Time to perform tasks
4. Accuracy of G&N sightings
5. Fuel usage
6. Accuracy of task analysis procedures.

10.3.4.8.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle E-5
2. LEM configuration access hatch
3. ILC pressure suits and constant-wear garment
4. Communications with command module, LEM, MDSS
5. Command module interior: latest Apollo design, display and controls, including G&N equipment.
6. Computers: analog and digital computer complex
7. Special LEM visual displays and external visual aids.

10.3.4.8.4 Facilities. Vehicle E-5, S&ID, Downey

10.3.4.8.5 Test Schedule. One year prior to actual mission

10.3.4.9 Systems Integration

Evaluation of a manned, large elliptical, approximately 70 kn mile apogee land or water recovery mission, to demonstrate a lunar mission capability.

10.3.4.9.1 Objectives. The objectives of this phase are:

1. Evaluate the timeline and crew task for the launch countdown operations
2. Evaluate crew task performance on a simulated lunar mission
3. Evaluate the timeline and task analysis for LEM/spacecraft/ground communications
4. Evaluate command module rescue capability with LEM as the passive vehicle
5. Determine crew interaction and performance during systems performance and reliability tests
6. Evaluate crew performance while determining G&N system accuracy
7. Validate task analysis for correct sequence of tasks
8. Evaluate task loading.

10.3.4.9.2 Test Plan.

10.3.4.9.2.1 Tasks. The crew will operate under the work-rest and task-analysis schedule for the lunar mission. Launch countdown operations, crew tasks, and LEM/spacecraft/ground communications will be evaluated. During the systems reliability testing, the crew interaction and performance will be evaluated. Crew performance while utilizing the G&N system will be evaluated.

10.3.4.9.2.2 Variables. The variables are:

1. Days
2. Command module interior lighting

3. Pressure garment assembly (pressurized versus nonpressurized versus constant-wear garment).

10.3.4.9.2.3 Measurements. The measurements to be made include:

1. Accuracy and efficiency of general performance over time
2. Efficiency of LEM/spacecraft/ground communications
3. Timeline task analysis accuracy of contingency requiring command module to rescue LEM
4. Accuracy of G&N sightings
5. Accuracy of task analysis procedures.

10.3.4.9.3 Equipment Requirements. The equipment required is as follows:

1. Special equipment: Crew systems test console
2. Command module interior
    a. Latest Apollo design display and controls.
    b. Simulated G&N equipment (with visual displays)
    c. Pressure garment assembly with provisions for vent air within test vehicle, constant-wear garments
    d. Two-way communications for MDSS simulation
    e. Television monitoring equipment
    f. Life support provisions (personal hygiene, medical, etc.).

10.3.4.9.4 Facilities. Vehicle E-5, S&ID, Downey

10.3.4.9.5 Test Schedule. One year prior to actual mission

10.3.4.10 Systems Integration

Evaluation of in-flight operations during a simulated manned earth orbit rendezvous and docking flight.

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10.3.4.10.1 Objectives. The objectives of this phase are:

1. Evaluate LEM/spacecraft/ground communications procedures
2. Evaluate crew task loading on a simulated lunar mission
3. Evaluate crew task loading during simulated emergency conditions
4. Evaluate crew ability to perform rendezvous tasks
5. Monitor crew physiological conditions
6. Evaluate food and wast management and personal hygiene procedures
7. Validate task analysis for correct sequence of tasks
8. Validate task analysis for crew integration compatibility.

10.3.4.10.2 Test Plan.

10.3.4.10.2.1 Tasks. Crewman will operate under the work-rest schedule and task assignments proposed for the fifth Saturn 1B manned earth orbit (rendezvous and docking flight). Tasks will involve systems operation and checkout, emergency situations, rendezvous, docking and simulated lunar mission, and will be programmed in accordance with expected mission parameters.

10.3.4.10.2.2 Variables. The variables are:

1. Various emergency conditions
2. Interior and exterior lighting and displays
3. Pressure garment (pressurized versus nonpressurized versus constant-wear garment)
4. Cabin and suit temperature and pressure.

10.3.4.10.2.3 Measurements. The measurements to be made include:

1. Various physiological measurements
2. Pilot error
3. Time to perform tasks

4. Fuel usage

5. Closure and drift rates at contact

6. Time for detection of emergency conditions

7. Accuracy of task analysis procedures

10.3.4.10.3 Equipment Requirements. The equipment required is as follows:

1. Vehicle E-5

2. LEM configuration access hatch

3. ILC pressure suits, back packs, 0_2 bottles and constant-wear garment

4. Communications with command module, LEM, MDSS

5. Command module interior: latest Apollo design, display and controls, including G&N equipment

6. Computers: analog and digital computer complex

7. Special LEM visual displays and external visual aids.

10.3.4.10.4 Facilities. Vehicle E-5, S&ID, Downey

10.3.4.10.5 Test Schedule. One year prior to actual mission

10.3.4.11 Systems Integration

A manned, earth-orbital land-recovery mission to evaluate in-flight operations with lunar mission propulsion capabilities.

10.3.4.11.1 Objectives. The objectives of this phase are:

1. Evaluate the timeline and task analysis for LEM/spacecraft/ground communications

2. Evaluate crew tasks on a simulated lunar mission

3. Evaluate crew and spacecraft equipment capability in simulated emergency conditions

4. Evaluate rendezvous capability (large orbital plane change by LEM)

5. Determine crew interaction and performance during systems operation and checkout

6. Validate task analysis for crew integration compatibility.

10.3.4.11.2 <u>Test Plan</u>.

10.3.4.11.2.1 Tasks. The crew will operate under the work-rest and task analysis schedule for the simulated lunar mission. Crew tasks and LEM/spacecraft/ground communications will be evaluated. Crew reaction to various simulated emergencies will be investigated. Crew and systems performance will be evaluated throughout the simulation. Rendezvous and docking design capabilities for several orbital plane changes by LEM will be investigated.

10.3.4.11.2.2 Variables. The variables are:

1. Command module interior lighting

2. Target identification lights

3. LEM orbital plane changes

4. Pressure garment assembly (pressurized versus nonpressurized versus constant-wear garment)

5. External sighting aids for rendezvous and docking.

10.3.4.11.2.3 Measurements. The measurements to be made include:

1. Accuracy and efficiency of general performance over time

2. Accuracy of crew timeline and task analysis during rendezvous and docking

3. Efficiency of LEM/spacecraft/ground communications

4. Accuracy of target monitoring through use of radar during rendezvous

5. Accuracy of final docking position attitude and rates

6. Total rotational and translational fuel expended

7. Accuracy of G&N sightings

8. Accuracy of attitude control and re-entry maneuver

9. Accuracy of task analysis procedures.

10.3.4.11.3 Equipment Requirements (Command Module Interior). The equipment required is as follows:

1. Latest Apollo design displays and controls

2. Simulated G&N equipment (with visual displays)

3. Simulated rendezvous radar controls and displays

4. Pressure garment assembly with provisions for vent air within test vehicle, constant-wear garment

5. Closed circuit Television monitoring equipment

6. Life support provisions (personal hygiene and medical equipment as required)

7. MDSS communications

8. Six degrees of freedom, LEM model.

10.3.4.11.4 Facilities. Vehicle E-5, S&ID, Downey

10.3.4.11.5 Test Schedule. One year prior to actual mission

10.3.4.12 Systems Integration

A manned, earth orbital, land recovery mission to evaluate in-flight operations (rendezvous and docking).

10.3.4.12.1 Objectives. The objectives of this phase are:

1. Evaluate crew tasks on a simulated lunar mission

2. Determine crew and spacecraft equipment capability in simulated emergency conditions

3. Evaluate crew interactions and performance during systems operation and checkout

4. Evaluate rendezvous and docking capability

5. Validate task analysis for correct sequence of tasks

6. Evaluate task loading.

10.3.4.12.2 <u>Test Plan</u>.

10.3.4.12.2.1 Tasks: The crew will operate under the work-rest and task analysis schedule for the simulated lunar mission. Contingency situations requiring diagnostic and corrective action by the crew will be evaluated. The crew will perform a complete rendezvous and docking task.

10.3.4.12.2.2 Variables. The variables are:

1. Command module interior lighting

2. Target identification lights

3. LEM descent trajectories

4. Pressure garment assembly (pressurized versus nonpressurized versus constant-wear garments)

5. External sighting aids for rendezvous and docking

10.3.4.12.2.3 Measurements. The measurements to be made include:

1. Accuracy of general performance over time

2. Total rotational and translational fuel expended

3. Accuracy of orbital changes

4. Final docking positions and rates

5. Ability to diagnose, evaluate, and correct malfunctions during contingencies

6. Accuracy of G&N sightings

7. Accuracy of attitude control and re-entry maneuver

8. Accuracy of task analysis procedures.

10.3.4.12.3 <u>Equipment Requirements (Command Module Interior).</u> The equipment required is as follows:

1. Latest Apollo design displays and controls
2. Simulated G&N equipment (with visual displays)
3. Simulated rendezvous radar controls and displays
4. Pressure garment assembly with provisions for vent air within test vehicle, constant-wear garments
5. Closed circuit Television monitoring equipment
6. Life support provisions (personal hygiene and medical care as required)
7. MDSS communications
8. Six DOF LEM model.

10.3.4.12.4 <u>Facilities.</u> Vehicle E-5, S&ID, Downey

10.3.4.12.5 <u>Test Schedule.</u> One year prior to actual mission

10.3.5 <u>Navigational Studies</u>

10.3.5.1 Sextant Evaluation Study

(Evaluation of sextant operation for mid-course navigation and IMU fine alignment.)

10.3.5.1.1 <u>Objectives.</u> The objectives of this phase are:

1. Establish operator performance parameters in carrying out sextant operations
2. Evaluate effects of G&N, SCS, RCS, and vehicle parameters on sextant operator's performance
3. Evaluate operator interfaces with controls and displays, pressure garment assembly, etc.
4. Evaluate operational procedures

5. Determine the most effective technique for sextant operation during navigational sightings

6. Verification of normal and manual modes of the flight crew task analysis with respect to performance time, correctness of task sequence, and operator accuracy.

10.3.5.1.2 <u>Test Requirements.</u>

10.3.5.1.2.1 Tasks. Subjects will perform sextant operation from the time of placing of the eye to the sextant eyepiece until the mark button is pressed.

10.3.5.1.2.2 Variables. The variables are:

1. Spacecraft random drift rates

2. Control modes

3. Alignment techniques

4. Impulse magnitude

5. Shirt sleeve versus pressure garment

6. Control conventions

7. Visual cue configurations

8. Single pulse versus chain of pulses.

10.3.5.1.2.3 Measurements. The measurements to be made include:

1. Time to complete alignment

2. Propellant usage in roll, pitch, and yaw

3. Alignment error

4. Residual rates at completion of sighting task.

10.3.5.1.3 <u>Equipment Requirements.</u> The equipment required is as follows:

1. Sextant: 1.8 -degree field of view with current optics system

2. Earth and lunar landmark display

3. Current minimum impulse configuration

4. Lower equipment bay control panel

5. Sextant eyepiece and current optics

6. Optics controller and rotational controller

7. Mark button

8. Target star and starfield visual displays

9. Computer and recording facilities capable of providing simulation of simplified spacecraft dynamics.

10. 3. 5. 1. 4 Facilities. Navigation sighting simulator, S&ID, Downey

10. 3. 5. 1. 5 Schedule. May 1964 (Figure 10-21)

10. 3. 5. 2 Telescope Evaluation Study

(Evaluation of telescope operation for mid-course and orbital navigational sightings.)

10. 3. 5. 2. 1 Objectives. The objectives of this phase are:

1. Establish operator performance parameters in carrying out telescope operation task, e. g., time, fuel, and error measures for the final part of the sighting task

2. Evaluate effects of G&N, SCS, RCS, and vehicle parameters on telescope operator's performance

3. Evaluate operator interfaces with controls and displays

4. Evaluate operational procedures

5. Determine the most effective technique for telescope operation

6. Verification of normal and manual mode of the flight crew task analysis with respect to performance time, sequence, and operator accuracy.

10. 3. 5. 2. 2 Test Requirements.

[redacted]

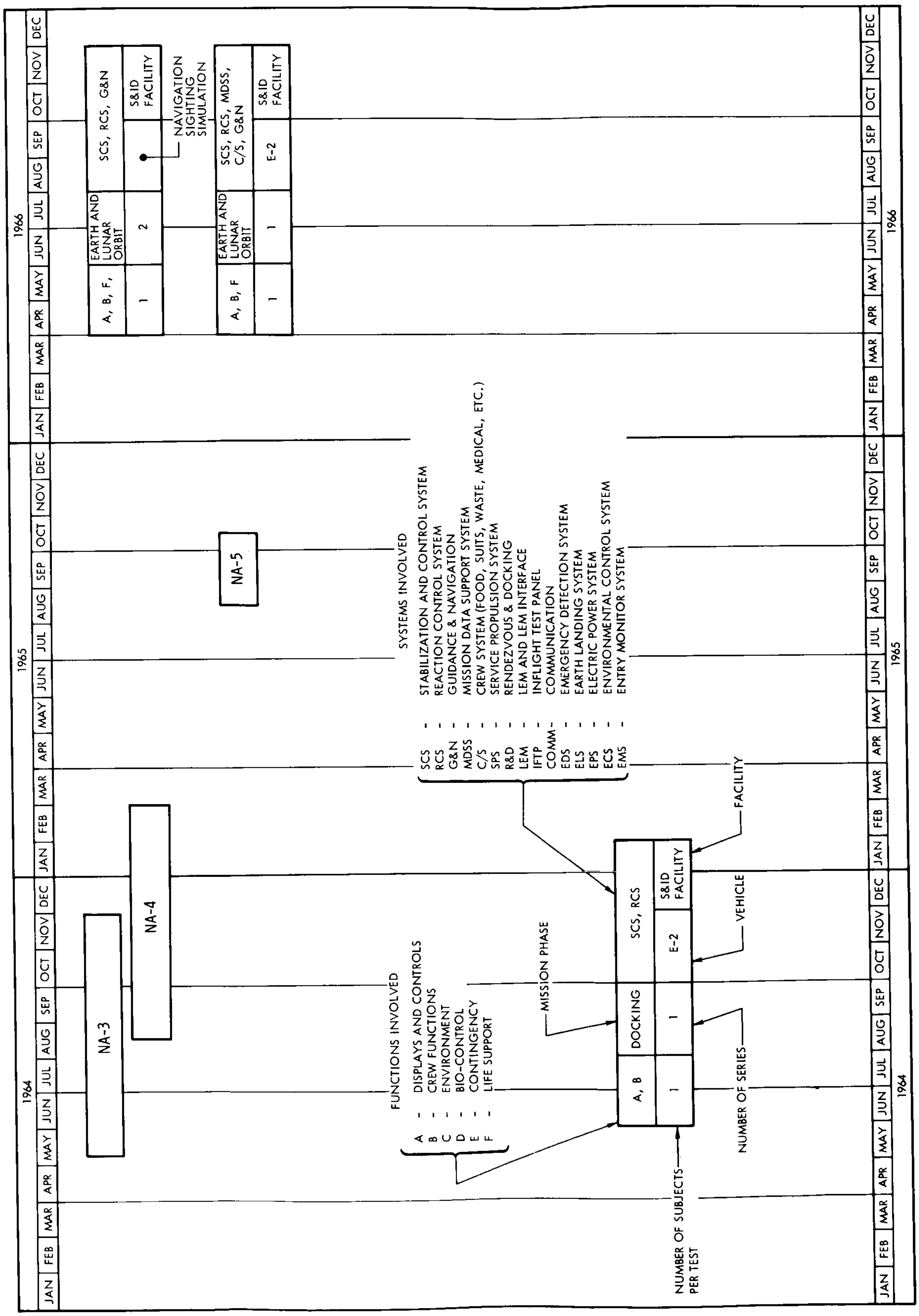

Figure 10-21. Navigation Test Schedule

[redacted]

10.3.5.2.2.1 Tasks. Subjects will perform telescope operation from the time of placing of the eye to the telescope eyepiece until sighting is completed.

10.3.5.2.2.2 Variables. The variables are:

1. Spacecraft drift rates
2. Control modes
3. Alignment techniques
4. Impulse magnitude
5. Shirt sleeve versus pressure garment assembly
6. Control conventions
7. Visual cue configurations.

10.3.5.2.2.3 Measurements. The measurements to be made include:

1. Time to complete sighting
2. Propellant usage, roll, pitch, and yaw
3. Sighting error.

10.3.5.2.2.4 Equipment Requirements. The equipment required is as follows:

1. Telescope with 60-degree and 20-degree fields
2. Earth and lunar landmark display
3. Current minimum impulse configuration
4. Lower equipment bay control panel
5. Telescope eyepiece and optics
6. Optics controller and rotational controller
7. Mark button
8. Target star and starfield visual displays

9. Computer and recording facilities capable of providing simplified dynamics.

10.3.5.2.4 <u>Facilities</u>. Navigation sighting simulator, S&ID, Downey

10.3.5.2.5 <u>Schedule</u>. August 1964

10.3.5.3 Navigation Sighting Study

(Evaluation of the operation of the guidance and navigation system by the integrated crew.)

10.3.5.3.1 <u>Objectives</u>. The objectives of this phase are:

1. Verify integrated task analysis
2. Evaluate adequacy of operator interfaces with controls, displays, pressure garment assembly, restraint harness, etc.
3. Establish optimum procedures for sightings
4. Investigate lost target re-acquisition techniques
5. Determine effects of changing visual field presentations (60°, 20°, 1.8°)
6. Verification of task analysis for failure mode and contingencies

10.3.5.3.2 <u>Test Requirements</u>.

10.3.5.3.2.1 Tasks. Subject will perform a complete navigation sequence including IMU fine alignment and ΔV maneuver for orbital and midcourse mission phases.

10.3.5.3.2.2 Variables. The variables are:

1. Task allocation
2. Control and display arrangement
3. Shirt sleeve versus pressure garment assembly
4. Visual cue configurations.

10.3.5.3.2.3 Measurements. The measurements to be made include:

1. Time period required to perform integrated navigation tasks

2. The proficiency with which integrated tasks are performed.

10.3.5.3.2.3 Equipment Requirements. The equipment required is as follows:

1. Lower equipment bay panel

2. Complete set of G&N station controls except IMU control, IMU CDU's, photometer gain and IMU temperature mode per MSC (drawing 1015006 dated 23 October 1963)

3. Simulated telescope and sextant, eyepieces and reticles

4. Current Apollo displays and controls

5. Pressure garment assembly

6. Communications

7. Crew couches

8. Restraint harness

9. Far earth and lunar landmark visual displays

10. Identifiable target star and starfield visual displays

11. Near earth and lunar orbital visual displays.

10.3.5.2.4 <u>Facilities</u>. E-2, S&ID, Downey

10.3.5.2.5 <u>Schedule</u>. August 1965

11.0 GROUND SUPPORT EQUIPMENT

11.1 SCOPE

A GSE engineering test plan that results in a systematic approach to performance and specification characteristics of each unit of Apollo GSE is essential. Engineering and design verification tests will be performed on selected GSE to assure that the equipment meets the applicable requirements of design and performance. Applicable test data at certain levels of testing will be integrated and analyzed to assist in the over-all improvement of the deliverable equipment. The tests are divided into the following classifications:

Development tests
Qualification tests
Acceptance tests

11.1.1 Development Tests

The development tests will be determined by the design unit. Development tests will be conducted for the following purposes:

1. Evaluate materials and parts to assimilate general intelligence and application suitability data.
2. Acquire design or process improvement information.
3. Develop assurance that it will pass the qualification tests.
4. Determine design approach as compatible with requirements of this specification.
5. Locate significant failure modes.

11.1.2 Qualification Tests

Unless otherwise specified, the qualification tests will be performed on a unit produced with the same tooling and processes and under the same conditions as those intended for quantity production. All qualification tests will be conducted to demonstrate design integrity in accordance with the

[redacted]

requirements of the specification. Qualification tests will be performed at the bay or console level. Modules, panels, and commercial equipment, therefore, will not be tested as end items.

11.1.3 Acceptance Tests

The acceptance test will be performed on each deliverable end item. Any failures will be cause for rejection.

11.1.3.1 Classification Tests

Testing will be classified as follows:

Examination of Product
Functional Test
Performance Test

11.1.3.2 Examination of Product

The units will be examined to determine that the construction is in accordance with the drawings and requirements of the Design Control Specification, with respect to materials, workmanship, dimensions, and marking.

11.1.3.4 Functional Test

The units will be functionally tested per written functional test specification. Following satisfactory completion of the functional tests, each unit will be marked with an acceptance stamp by a representative of Quality Control.

11.1.3.5 Performance Test

The units will be tested with all associated items, including the spacecraft system. Only one test will be performed.

11.1.4 Rework

In the event any unit fails any part of the acceptance tests, the contractor may reject the entire lot of which the failed unit is representative and return to the subcontractor any unit of the lot which has been accepted. Upon satisfactory correction of the fault the unit as corrected may be resubmitted for acceptance tests. Documentation evidence of the rework will be submitted to the contractor.

11.1.5 Acceptance Test Record

A record of all acceptance tests will be maintained.

11.1.6 Failure Reporting, Analysis, and Feedback System

Detailed malfunction data will be recorded as a part of the normal equipment testing operations. All failures will be analyzed and a corrective action implemented. Supplier forms to be used for reporting malfunction and corrective action will be in accordance with MC999-0025. The designation, "retest OK" is not acceptable; a complete analysis will be accomplished for all failures.

11.1.7 Adjustments and Repairs During Tests

There will be no adjustments, repairs, or maintenance other than those specified in the acceptance specification during testing. All items requiring repairs will be completely retested.

11.2 ECS SUBCONTRACTOR TEST PLAN (AIRESEARCH)

The environmental control system ground support equipment is to be built and tested by the AiResearch Manufacturing Division. This program encompasses the total effort required to support the study, design and development, qualification, manufacturing, assembly, and operational support of the GSE to be built by AiResearch. Applicable test data at all levels of testing (component, subsystem, and/or system) will be integrated and analyzed to assist in the over-all improvement of the delivered equipment.

11.2.1 Objectives

The objective of the AiResearch test program is to obtain evidence in the form of test data to confirm that the component and system design concepts are sound and that the equipment will operate properly when exposed to single or combined environmental operating conditions. This will assure the delivery of functionally qualified hardware.

11.2.2 Test Plan

The test plan for the ECS-GSE consists of three phases as follows:

Phase I	Development tests
Phase II	Qualification tests
Phase III	Integrated system verification tests

11.2.2.1 Phase I: Development Tests

Developmental tests are to be performed on the following two specific classes of GSE.

11.2.2.1.1 Direct Mission Essential Equipment. GSE in this category (Numbers refer to AiResearch part numbers) includes:

Water-glycol service unit 844700
Water-glycol trim control set 845800

The objective of the tests conducted on this equipment is to determine the functional capability of each GSE end item during a simulated countdown procedure. This will be accomplished by integrating the GSE with the ECS and conducting tests simulating precountdown, countdown, and postlaunch.

11.2.2.1.2 Indirect Mission Essential Equipment. GSE in this category (Numbers refer to AiResearch part numbers) includes:

Low-pressure gaseous test stand 844000
High-pressure gaseous test stand 844100
Liquid test stand 844200
Pressure distribution unit 845100
Suit loop stimuli generator 827510
Major subassembly bench maintenance test stand (AiResearch part number not yet assigned)
Water bench maintenance test stand
Water glycol bench maintenance test stand

The objective of the tests conducted on this equipment will be to verify the instrumentation accuracy of each of the GSE test stands listed and its functional capability to check out the ECS components.

11.2.2.2 Phase II: Qualification Tests

As in Phase I tests, qualification tests will be run on direct and indirect mission essential equipment. In both categories of GSE, the test objectives will be to determine that the end items meet the performance requirements of their respective specifications and that the GSE shipping containers adequately protect the end items.

11.2.2.3 Phase III: Integrated System Verification Tests

Two complete ECS in-flight test and maintenance GSE systems will be tested to determine that the integrated system will meet the operational performance requirements under the combined environmental conditions of a simulated countdown and launch. In addition, data will be obtained on the operational life characteristics of the entire system.

11.2.3 Equipment

The new space and environmental systems laboratory will include the following:

1. Hard-vacuum chambers for component testing
2. Low-pressure chambers for subsystem and system testing
3. Vibration shake tables
4. High-low-temperature chambers
5. Miscellaneous bench-test equipment
6. Instrumentation including analog recording and digital readout and monitoring systems
7. High-vacuum and condenser blowdown system

In addition to the test equipment listed above, a new clean room with facilities for cleaning, testing, and packaging components, subsystems, and systems will be included in the new facility.

11.2.4 Facilities

The principal facilities of the AiResearch Manufacturing Company, which will be utilized for the Apollo Project, consist of two major manufacturing and laboratory installations and a remote desert test site. The main manufacturing facilities are located in Los Angeles and Torrance, California. The remote test facility is located at Boron, California. The design, development, and manufacture of the GSE for the ECS will be done at those facilities, each of which has an area exclusively devoted to the Apollo Program.

11.2.4.1 Manufacturing

The Los Angeles plant includes approximately 310,000 square feet of factory and warehouse area and approximately 74,000 square feet of engineering office area. It is not anticipated that additional building, or major modification of existing buildings, will be required for the manufacture of Apollo ECS-GSE.

11.2.4.2 Research and Development

The Los Angeles laboratory of AiResearch, including the Torrance and Boron facilities, occupies approximately 188,000 square feet of floor space. AiResearch funds are being used in the upgrading of these existing facilities to meet the requirements of the Apollo Program.

11.2.4.3 Testing

In addition to existing facilities, a new space and environmental systems laboratory with 22,000 square feet of floor space will be completed November 1963, at the Torrance plant. This laboratory, funded by AiResearch, will be designed specifically to test space and environmental control systems.

11.2.5 Test Schedule

The schedule for the environmental control system prototype GSE is presented in Figure 11-1.

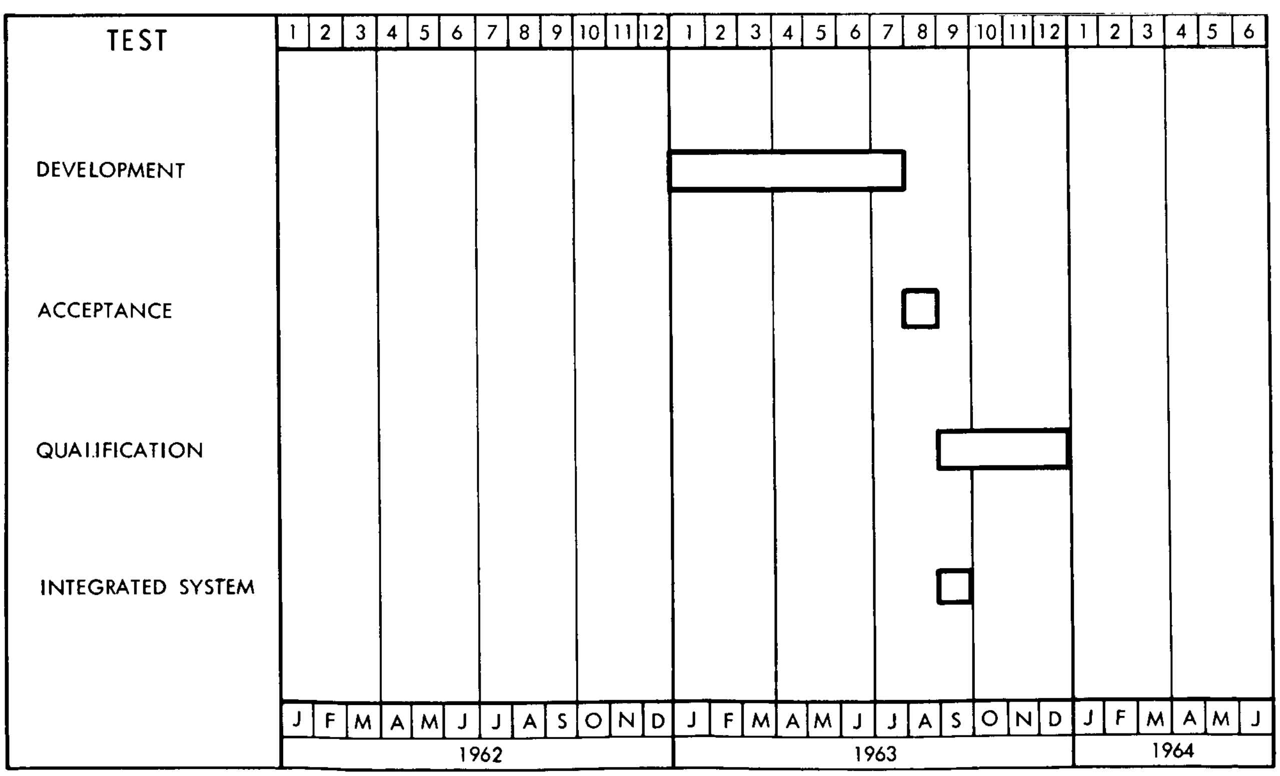

Figure 11-1. Environmental Control System Prototype GSE Schedule

11.3 SCS SUBCONTRACTOR TEST PLAN (MINNEAPOLIS-HONEYWELL)

The stabilization and control system GSE which consists of a bench maintenance test set, bench maintenance card tester and the auxiliary GSE will be manufactured and tested by the Minneapolis-Honeywell Regulator Company.

11.3.1 Objectives

Development, design evaluation, qualification, and acceptance tests will be performed to assure that the equipment meets all applicable requirements of design and performance. The tests will provide information in the form of test data which will demonstrate the compatibility of the GSE with the spacecraft, and also verify that the equipment will perform its function adequately and reliably.

11.3.2 Test Plan

The SCS-GSE test program will consist of the following tests.

Development tests
Design Evaluation tests
System GSE integration tests
Qualification tests
Acceptance tests

11.3.2.1 Development tests

11.3.2.1.1 Circuit Development Tests. During circuit analysis work, physical circuit hardware is built up and tested to prove out paper-work studies. As changes occur in flight hardware, the affected circuits for GSE will be incorporated and checked out for compatibility and integration into the final configuration.

11.3.2.1.2 Design Evaluation Tests. During this phase, an engineering evaluation testing of parts to select those suitable for use in the SCS-GSE will be conducted. This will include such studies as:

Determination of characteristics
Compartive tests to aid in selection
Evaluation of critical environments
Determination of performance stability and repeatability
Evaluation of changed and/or improved design

[redacted]

11.3.2.2. System-GSE Integration Tests

The bench-maintenance console will be checked out with the actual SCS system to demonstrate compatibility with the system.

11.3.2.3 Qualification Tests

This phase consists of a comprehensive series of performance tests conducted on panels or systems to demonstrate that the equipment meets all applicable requirements of design and performance.

11.3.3 Equipment

The following test equipment will be used in the test program.

Miscellaneous general-purpose instrumentation
GSE auxiliary equipment
Simulated SCS system loads
C-125 vibration simulator
Shock machine
Fungus chamber, Honeywell
Salt-spray chamber, Honeywell
Humidity chamber, Honeywell
High-low temperature chamber, Honeywell

11.3.4 Facilities

The tests will be performed at the Honeywell Aero Division facilities in Minneapolis and Roseville, Minnesota.

11.3.5 Test Schedule

The schedule for the stabilization and control system GSE is presented in Figure 11-2.

11.4 SUBCONTRACTOR TEST PLAN (PRATT & WHITNEY AIRCRAFT)

The fuel-cell power plant test stand will be constructed and tested by the Pratt & Whitney Aircraft Company. The test-stand test program encompasses the total effort required to support the study, design, development, qualification, and manufacturing of the fuel-cell test stands.

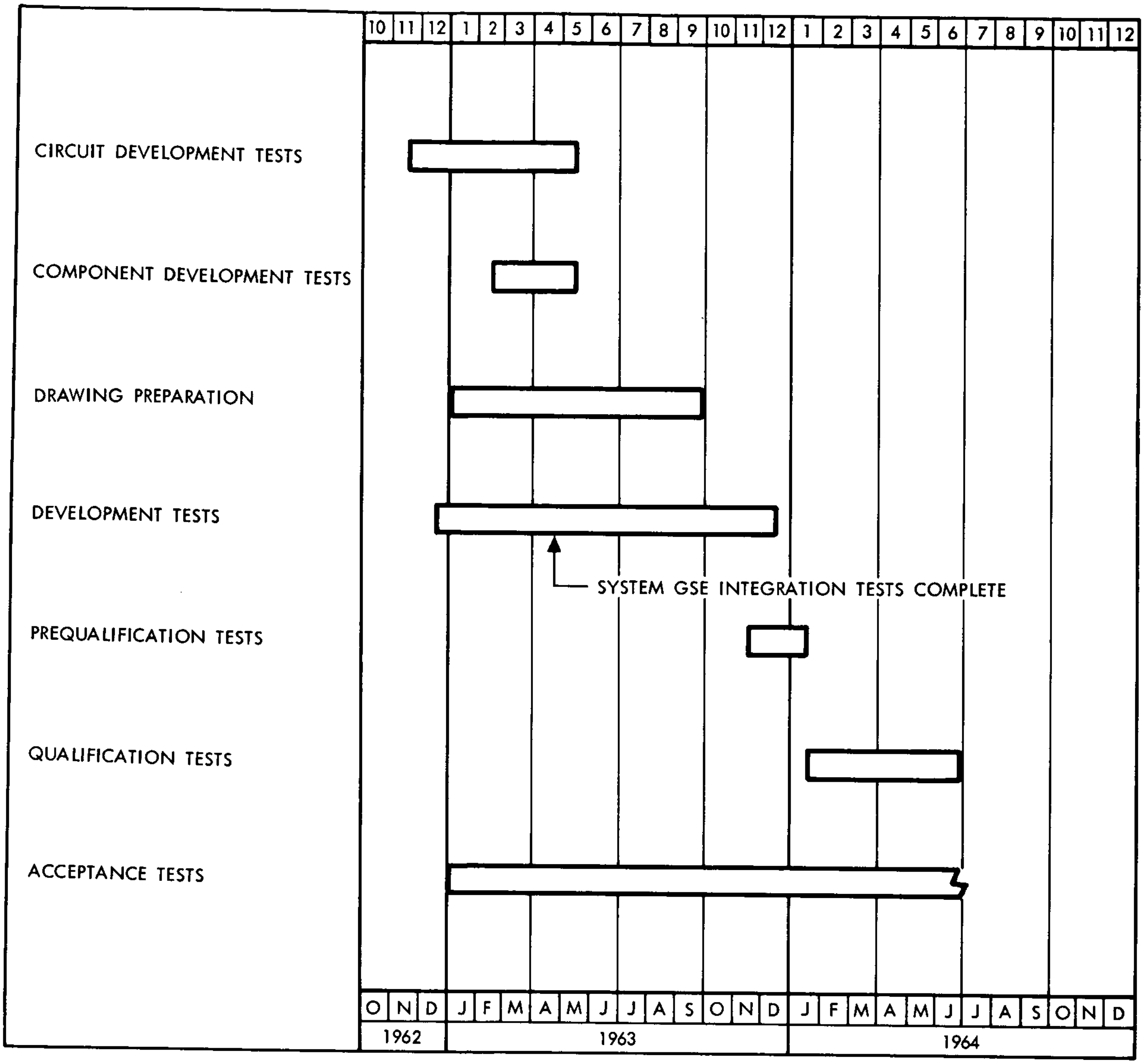

Figure 11-2. Stabilization Control System GSE Schedule

11.4.1 Objectives

The objective of the test program is to provide test data which will verify that the fuel-cell test stands function in accordance with the specifications and design requirements that have been established.

11.4.2 Test Plan

The inspection and testing of the test stands shall be divided into two phases.

11.4.2.1 Acceptance Tests

Each delivered unit shall be subjected to the following tests.

Examination of product (conformance to drawings and workmanship, etc.)
Dielectric
Operating (functional)

11.4.2.2 Qualification Tests

The extent of the qualification tests has not been determined at this time.

11.4.2.3 Operating Tests

The test stand shall be subjected to the following operating tests. During the operating tests, the test stand shall exhibit no malfunctioning, leaks, or other irregular operation.

11.4.2.3.1 Gas Supply System Test. The gas supply system shall be subjected to the following tests.

1. Leakage test. The gas supply system shall be pressurized with helium to 60 psia. Leakage shall be measured by pressure decay. The following maximum leakage rates shall apply.

Location	Power plant side of shut-off valves (cc/hr)	Supply side of shut-off valves (cc/hr)
Oxygen passages	5	100
Hydrogen passages	5	100
Nitrogen passages	5	500

The shut-off valves shall be closed.

2. Pressure regulator test. The gas supply system shall be connected to a nitrogen container and the following regulation demonstration shall be conducted.

Location	Minimum flow rate (lb/hr)	Maximum flow rate (lb/hr)
Oxygen passages	1.5	2.5
Hydrogen passages	0.75	11.0
Nitrogen passages	0.75	11.0

Location	Minimum pressure Power plant side (psia)	Maximum pressure Power plant side (psia)
Oxygen passages	250	1000
Hydrogen passages	100	300
Nitrogen passages	50	1500

The above shall be demonstrated with the nitrogen container at 2500 psia and at 1100 psia.

11.4.2.3.2 Data Readout System Test. The data readout system shall be operated to insure qualitatively the proper functioning of the equipment, including all operating controls.

1. Calibration stability tests. The following tests shall be conducted to establish compliance with accuracy requirements in the performance section of this specification.

   (a) The calibration of all measurement channels shall be established at 105, 115, and 125 volts.

   (b) The calibration of all measurement channels shall be established at periodic intervals over a period of 20 hours.

2. Linearity tests. The linearity of the readout system will be checked to establish compliance with the performance section of this specification.

11.4.2.3.3 Load Absorption System Tests. Tests shall be conducted to demonstrate the ability of the load absorption system to perform in accordance with the performance requirements of this specification. The load, when set at a predetermined level, shall not vary in excess of 5 percent of the set load.

[redacted]

11.4.2.3.4 Heat Rejection System Test. The unit shall demonstrate the ability to maintain a maximum temperature of the glycol mixture supply to the module of 175 degrees F at 80 pounds per hour glycol flow rate with clean, demineralized water supplied at a minimum of 70 degrees F and at a maximum pressure of 30 psia.

11.4.2.3.5 Power Output System Test. The power output system shall be operated to insure compliance with the performance requirements of this specification.

11.4.2.3.6 Dielectric Strength. The equipment shall be subjected to the dielectric withstanding voltage test, Method 301 of Standard MIL-STD-202. The test voltage shall be 1000 volts at commercial frequency and shall be applied between all circuits and the connector cases and the chassis. Immediately following this test, the equipment shall be tested in accordance with 11.4.2.3.7 and 11.4.2.3.8. Instrumentation circuits and components shall not be subjected to this test.

11.4.2.3.7 Insulation Resistance. The test stand shall be subjected to the insulation resistance test, Method 302 of Standard MIL-STD-202, test condition B. The potential shall be applied between each circuit and all other nonconnected circuits, the connector cases, and the chassis or frame, as applicable. The insulation resistance of each circuit shall be a minimum of 30 megohms.

11.4.2.3.8 Continuity. The continuity of each circuit of the test stand shall be verified to be in accordance with the test stand wiring diagrams and shall be checked by means of any commercial checking device or production test equipment employing such devices with an impressed voltage of 6.0 volts or less.

11.4.2.3.9 Leak Detector. The test stand shall be operated to insure proper functioning of the equipment. Test shall be conducted to establish conformance with fuel leakage and oxidizer leakage allowances.

11.4.3 Test Equipment

Equipment used to measure item parameters shall not introduce an error greater than 20 percent of the tolerance on the parameter. If a parameter tolerance is plus or minus 10 percent, the equipment error shall not be greater than plus or minus 2 percent.

The following categories of test equipment shall be used.

Electrical instruments
Pressure indicators
Temperature indicators
Flow indicators
PH indicators

11.4.4 Facilities

The acceptance tests on the fuel-cell test stands will be performed at the Pratt & Whitney Aircraft facility in Hartford, Connecticut. The test facility is equipped with hydrogen, oxygen, and nitrogen gas.

11.4.5 Schedule

The test schedule has not been determined at this time but will be included in the 31 March 1964 revision of this document.

11.5 COMMUNICATION AND DATA (C&D) SUBSYSTEM SUBCONTRACTOR TEST PLAN (COLLINS RADIO COMPANY)

11.5.1 Objectives

The objective of the test plan is to provide test data which will verify that the communications and data bench maintenance equipment (BME) will perform in accordance with established specifications and design requirements and to ascertain its compatibility with the applicable spacecraft equipment.

11.5.2 Test Plan

The C&D-BME test program will be divided into the following categories.

11.5.2.1 Engineering Development Tests

Engineering development tests will be performed on development models by design engineers to establish feasibility of design approach and to develop the design to operational maturity. Various phases of development tests are as follows:

Circuit development tests on nonstandard BME components
Component development tests on nonstandard BME components
Design evaluation tests on complete BME

[redacted]

11.5.2.2 Qualification Tests

Qualification tests may be conducted by Collins Radio Company to certify the C&D-GSE performance characteristics under specified environmental conditions. Testing shall not be required if objective evidence of specification compliance can be satisfied by any of the following documentation.

1. Data derived from recent qualification tests conducted on equipment similar in design and utilization

2. Data derived from development tests related to the specific component designed by CRC

3. Vendor certificate of compliance on standard commercial test equipment qualified by similar field application

11.5.2.2.1 Electromagnetic Interference Tests. These tests shall be performed on one deliverable end item in accordance with the requirements of the specification.

11.5.2.3 Acceptance Tests

Acceptance test will be made on each deliverable BME end item in order to determine compliance with the design and applicable specifications. The following are the categories of tests to be conducted during acceptance tests. Specific requirements will be delineated in a subsequent issue of this document.

11.5.2.3.1 Examination of Product. This test will determine that the end item conforms in all respects to the workmanship, configuration, size, etc., and is in accordance with all applicable drawings as specified.

11.5.2.3.2 Operating Tests. These tests will determine that the BME components (standard and nonstandard) provide signals and readout indication which are in accordance with specification requirements.

11.5.2.3.3 Spacecraft Equipment Package/BME Compatibility Tests. These tests will determine that the GSE is compatible with input/output requirements of applicable spacecraft packages and in no way will degrade their performance.

11.5.2.3.4 Spacecraft Subsystem/BME Compatibility. This test will determine that the GSE has the capability to check out spacecraft subsystem performance in open test (packages operated as they are normally interconnected in spacecraft installation).

11.5.3 Equipment Requirements

The following equipment will be available at CRC for the test support of C&D-GSE. Specific model numbers will be included in a subsequent issue of this document.

1. Temperature chamber
2. Altitude chamber
3. Humidity chamber
4. Vibration table
5. Shock impact table
6. RFI measuring equipment
7. Voltage and frequency standards
8. Miscellaneous standard test equipment

11.5.4 Facilities

The principal facility to be utilized during the BME program will be the Cedar Rapids Division of Collins Radio Company. Subtier efforts will be required during the design and development phase of nonstandard BME components. Subtiers of CRC are as follows:

Motorola, Inc., Chicago, Illinois (S-Band equipment)
ACF Industries, Inc., Paramus, New Jersey (C-Band equipment)

11.5.5 Test Schedules

Figure 11-3 describes tentative test schedules for the C&D subsystem GSE.

11.6 S&ID TEST PLAN (GSE HANDLING EQUIPMENT)

Design verification testing of GSE handling equipment will be performed by S&ID. The test program will include fit, function, and structural tests, designed to provide reliable hardware.

[redacted]

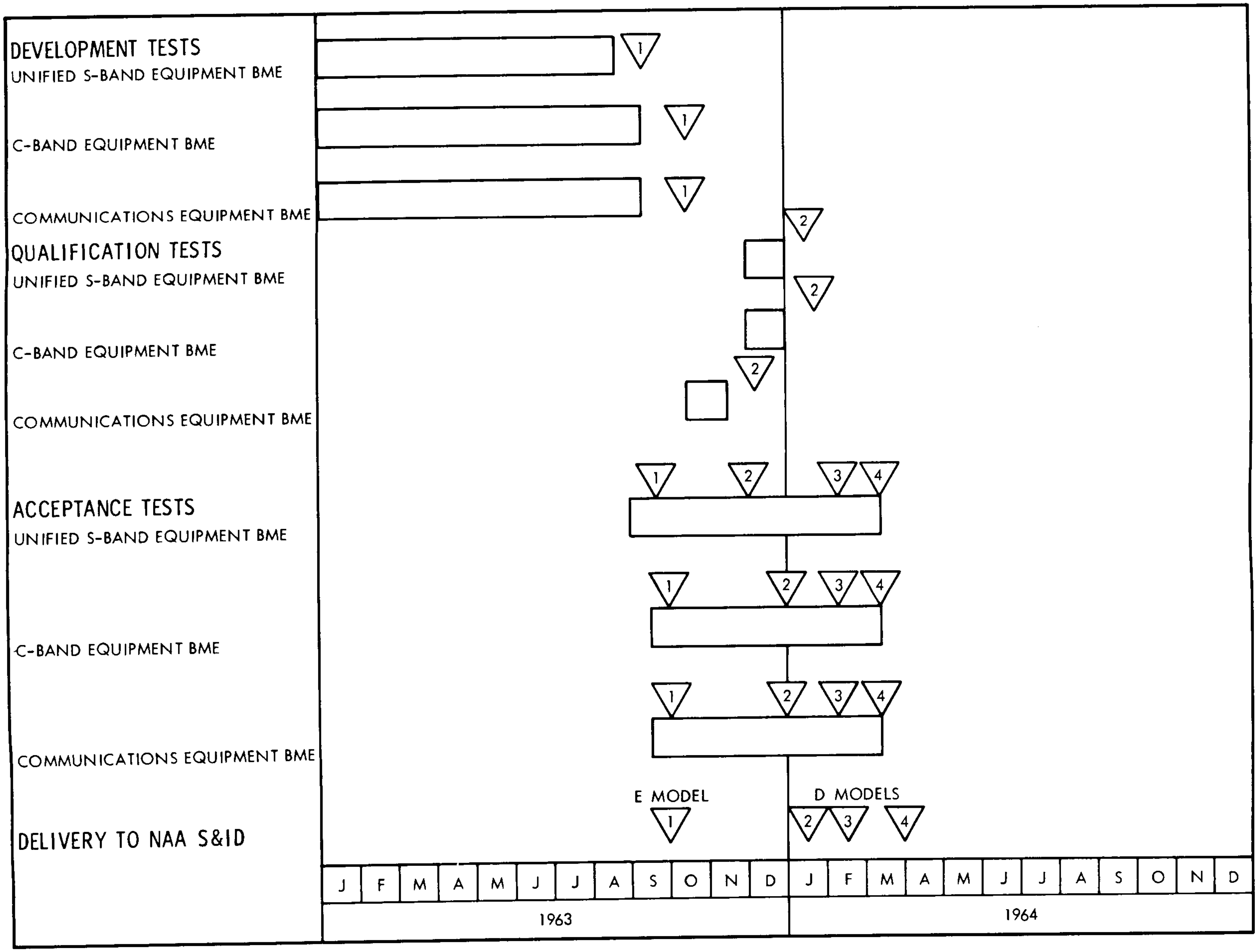

Figure 11-3.. Communications and Data Subsystem GSE Test Schedule

[redacted]

The handling equipment is classified by categories as follows:

Positioning equipment
Transporting equipment
Work stands
Weight and balance fixtures

11.6.1 Objectives

The objectives of the test program are:

1. To demonstrate interface compatibility between spacecraft modules and GSE
2. To verify handling methods and procedures
3. To demonstrate structural integrity
4. To establish deflection and mobility characteristics

11.6.2 Test Plan

11.6.2.1 Positioning Equipment (Slings, Dollies, Support Bases)

1. Perform static structural tests as outlined in section 12.2.22
2. Perform fit and function tests using airframe and/or mock-up components
3. Perform qualification tests as defined in the detailed procurement specifications

11.6.2.2 Transportation Equipment (Trailers)

1. Perform static proof-loading tests as outlined in section 12.2.22
2. Perform fit and function tests using airframe and/or mock-up components
3. Perform qualification tests as defined in the detailed procurement specifications

11.6.2.3 Work Stands

1. Perform fit and function tests using airframe and/or mock-up components

2. Perform qualification tests as defined in the detailed procurement specifications

11.6.2.4 Weight and Balance Fixtures

1. Perform static structural tests as outlined in section 12.2.22

2. Perform fit and function tests using airframe and/or mock-up components

3. Qualification tests have not been defined at this time

11.6.3 Facilities

Tests will be performed at S&ID, Downey.

11.6.4 Schedule

The test schedule will be included in a subsequent revision of this test plan.

11.7 S&ID TEST PLAN (FLUID SYSTEMS GSE)

This plan covers the testing required to support the development and certification of fluid systems GSE.

11.7.1 Objectives

The GSE test plan objectives are:

1. To develop components and subsystems to the degree required to assure suitability and compatibility

2. To demonstrate compatibility and suitability of end-item systems with the system they are designated to support

3. To demonstrate that end-items and/or components are capable of satisfactorily performing under extreme environments

4. To monitor human engineering aspects during operation of equipment

5. To note suitability of safety provisions, and to verify that unsafe conditions have been minimized

6. To test the servicing provisions of the GSE by simulating servicing requirements

7. To establish the resistance of GSE to shock and vibration conditions

8. To observe equipment during other operational tests and ensure that undesirable characteristics such as smoke, fumes, noise, vibration, heat, etc., have been minimized to the greatest possible extent

11.7.2 <u>Test Plan</u>

11.7.2.1 Development Tests

During development tests, parameters of specific components and subsystems will be measured to provide engineering with data which will lead to the optimum design. These parameters will include pressure, temperature, flow, capacity, response times, and efficiency.

11.7.2.2 Design Evaluation and Acceptance Tests

Design evaluation and acceptance tests will be performed on the final design and completed end-items of the equipment to demonstrate satisfactory operation. These tests are concerned with ensuring proper output and input interface conditions in terms of pressure, temperature, flow, response time, capacity, efficiency, and safety.

11.7.2.2.1 <u>Leak Tests</u>. Leak tests will be conducted to assure there is no external leakage to the fluid system when the system is subjected to external working pressures. Hydraulic and pneumatic components will be subjected to proof-pressure tests to assure that no internal leakage detrimental to operation of the various units will exist.

11.7.2.2.2 <u>Handling Provision Tests</u>. Handling provisions will be tested to demonstrate servicing means are simple, safe, and compatible with associated servicing equipment.

11.7.2.2.3 <u>Dielectric Strength Tests</u>. Electrical components will be subjected to dielectric withstanding voltage tests, Method 301 of MIL-STD-202.

11.7.2.2.4 Insulation Resistance Tests. Electrical components will be subjected to insulation resistance tests, Method 302 of MIL-STD-202, test condition "B". The insulation resistance of each circuit shall be a minimum of 30 megohms.

11.7.2.2.5 Servicing Provisions. Servicing provisions will be tested to demonstrate servicing means are simple, safe, and compatible with associated servicing equipment.

11.7.2.3 Qualification Tests

11.7.2.3.1 Air Transportability Tests. Conformance with specification MIL-A-8421 will be verified.

11.7.2.3.2 Mobility Tests. Mobility of units will be demonstrated for compliance with specification MIL-M-8090 where applicable.

11.7.2.3.3 Environmental Tests. High-temperature and low-temperature tests will be conducted on the various units to determine the resistance of the equipment to the temperature extremes. Tests will be determined for each individual unit.

11.7.2.3.4 Humidity Tests. Humidity tests will be conducted on the various units to determine the resistance of equipment to the effects of exposures to a warm, highly humid atmosphere.

11.7.2.3.5 Salt Fog Tests. A salt fog test will be conducted on items of equipment that will be situated in unsheltered areas to determine the resistance of the equipment to the effects of a salt atmosphere.

11.7.2.3.6 Sand and Dust Tests. Sand and dust tests will be conducted on items of equipment situated in unsheltered areas to determine the resistance of the equipment to blowing sand and dust particles.

11.7.2.3.7 Vibration Tests. Vibration tests will be conducted on the various units to determine the effects of vibration on items with vibration isolators, and on others. Test procedure will be according to MIL-E-4970, as applicable.

11.7.2.3.8 Shock Tests. Shock tests will be conducted on the various units to determine the effects of shock. Test procedure will be per MIL-E-4970, as applicable.

11.7.2.3.9 Rain Tests. Rain tests will be conducted on units located in unsheltered areas, mainly to determine the efficiency of protective covers or cases designed to shield equipment from the elements.

11.7.2.4 Test Requirements

11.7.2.4.1 Fluid Transfer Units. Tests will be conducted on the fluid-transfer units to assure that objectives stipulated in paragraph 11.7.1 have been achieved.

The following parameters will be monitored.

1. Inlet pressures, temperatures, flow-rates, or quantity transferred aboard the spacecraft

2. Inlet and outlet temperatures, fluid pressures, and flow-rates from the transfer units

3. Time required to transfer required amount of fluids aboard spacecraft

The proper sequencing of system component functions will be verified. Leak-tight fluid and pneumatic systems also will be verified.

11.7.2.4.2 Checkout Units. A test will be conducted on checkout units to assure that all objectives stated in paragraph 11.7.1 have been achieved. Pressures and temperatures of pressurizing gases will be monitored to assure that excessive pressure drops do not exist in the fluid systems. Operation of various system components and leak-tight fluid and pneumatic systems will be verified. Proper operation of pressure regulating devices will be assured.

11.7.3 Equipment

Environmental chambers and associated equipment.

High-temperature chamber
Low-temperature chamber
Humidity chamber
Exposure chamber (salt fog tests)*
Fungus chamber*
Sand and dust Chamber*
Rain chamber*
Vibration machine
Leak detection devices
Flowmeters
Pressure gauges

*To be available for testing unsheltered end-items.

[redacted]

Temperature indicators
Timers
Meggers
Volt-ohm-meters
Ammeters
Watt meters
Recorders
Calibration equipment
Oscilloscopes
Audio frequency generators
Vacuum-tube volt meters
Signal generators

11.7.4 Facilities

Tests will be performed at S&ID, Downey.

11.7.5 Schedule

The test schedule will be included in a subsequent revision of this test plan.

11.8 S&ID TEST PLAN (CHECKOUT GSE)

11.8.1 Objectives

The objective of this plan is to support the development, design evaluation, and qualification and acceptance testing of the checkout GSE. The checkout GSE is divided into two general categories.

Manually operated checkout GSE
Automated checkout GSE

11.8.2 Test Plan

11.8.2.1 Development Tests

Electronic and mechanical functions will be analyzed to make a preliminary identification of the type of circuit and class of components to be used. On the basis of this analysis the nominal input-output values and component operational values will be defined. An engineering development laboratory test will then be conducted to establish and verify the feasibility of the circuits and the nominal input-output and component operational values. Any discrepancies between the empirical analysis and the laboratory test will be resolved prior to further design.

Further tests will then be conducted to compare and verify results of worst case and parameter variation analysis. These tests will consist of varying each of the circuit parameters through their worst case tolerances.

Measurements will be made on the input/output and component parameters, and comparison will be made between the measured values and the values predicted during the analysis phase. Any deviations from the predicted values will be investigated, and the reason for the deviations determined. The analysis will be corrected, and the circuit or function will be retested until the deviation falls within the expected value.

11.8.2.1.1 Design Evaluation Tests. Design evaluation tests will consist of applying the checkout system to the GSE verification simulator to demonstrate its ability to perform an adequate checkout. This test program will provide the necessary GSE for house spacecraft 1 and serve to further qualify the GSE.

The test article used in the design evaluation test will be an advanced R & D set of checkout equipment, incorporating the design features generated in the development tests. In addition, output recorders and miscellaneous laboratory test instruments will be used.

The test procedures will be established by Apollo Systems Test.

11.8.2.2 Qualification Tests

Qualification tests will be performed to demonstrate the ability of checkout system GSE to withstand the applicable environmental stresses without degradation of performance. Measurements of the systems generation of EMI as well as immunity to EMI will be made.

The test article will consist of a complete set of prototype checkout equipment. The test equipment will include:

Environmental test facility
S/C simulator and related equipment
EMI measurement facility

The general procedure will be dependent upon the design criteria applicable at the time of qualification.

11.8.2.3 Acceptance Tests

Acceptance tests will be performed on each deliverable end item of GSE. The objective of these tests will be to verify complete physical and functional compliance with all design documents.

The acceptance tests will be performed in two phases. The first phase consists of factory tests which verify that the equipment conforms to the drawings and all applicable specifications. The second phase will be a complete functional test which verifies that the equipment correctly performs all required functions.

[redacted]

The acceptance test article will consist of a deliverable set of checkout equipment.

The test equipment will include:

S/C or S/C simulator
Input/output equipment and data recorders
Functional test process specification
Test procedures

11.8.2.4 Automatic Checkout Systems Test Plan

11.8.2.4.1 Objectives

1. To assure qualification of individual concepts and to make a preliminary evaluation of the data handling system

2. To evaluate over-all system performance and to determine the statistical reliability of the system

3. To solve the timing problems which will be involved and verify qualification of solutions

4. To develop satisfactory data formats and their effect on programming and logic complexity

5. To develop and verify self-check and auto-check methods and to eliminate verification simulator redundancy

6. To verify the functional integrity of checkout systems GSE and ACE and their compatibility with the spacecraft systems

7. To determine the adequacy of ACE in detection and isolation of critical systems failure down to the lowest replaceable module

11.8.2.4.2 ACE Development Tests. ACE consists of two basic systems, the command system (up-link) and the response system (down-link). There will be two engineering breadboards (1 and 2). The breadboard will be like the prototype in function only. It will not be fully expanded; it will, however, contain a sufficient number of data channels to demonstrate its engineering function.

11.8.2.4.2.1 Phase 1 Tests. The first phase will consist of tests of ACE circuits, subsystems, and individual systems. The basic purpose of these tests is to study the feasibility of the present checkout concept and to give preliminary evaluation of the proposed data handling system. The following are detailed objectives:

1. Evaluate the performance of local subcommutators and optimize their design

2. Evaluate analog to digital conversion techniques

3. Evaluate the PCM subsystem

4. Study compatibility of various components with each other.

The procedure will consist of running performance tests on the system components. These components will then be connected to their interfaces and operated as a subsystem or system. The two system tests and their objectives are listed below.

1. Command System Test

   The DTCS Model C14-231 will undergo the following tests, with the command word generator to supply input signals and the command monitor and display unit to display the output. Configuration will be as shown in Figure 11-4. Tests will be conducted according to Test Procedure MA 0201-0228.

   a. Check of compatibility with the DTCS and the command word generator

   b. Calibration check of analog modules

   c. Verification of the operation of internal self-check circuitry.

2. Response System Test

   The C14-210 Carry-On PCM Subsystem, the C14-211 through C14-215 Substitute Unit, and the C14-240 Servicing Equipment ACE-S/C Adapter Substitute Unit will be set up in the configuration shown in Figure 11-5 to supply two of the data input channels to the C14-230 Data Interleaver. The remaining channels will be supplied by the PCM signal simulator. The tests will be conducted according to PCM Response Data System Test Procedure MA 0201-0229 and will include the following:

[redacted]

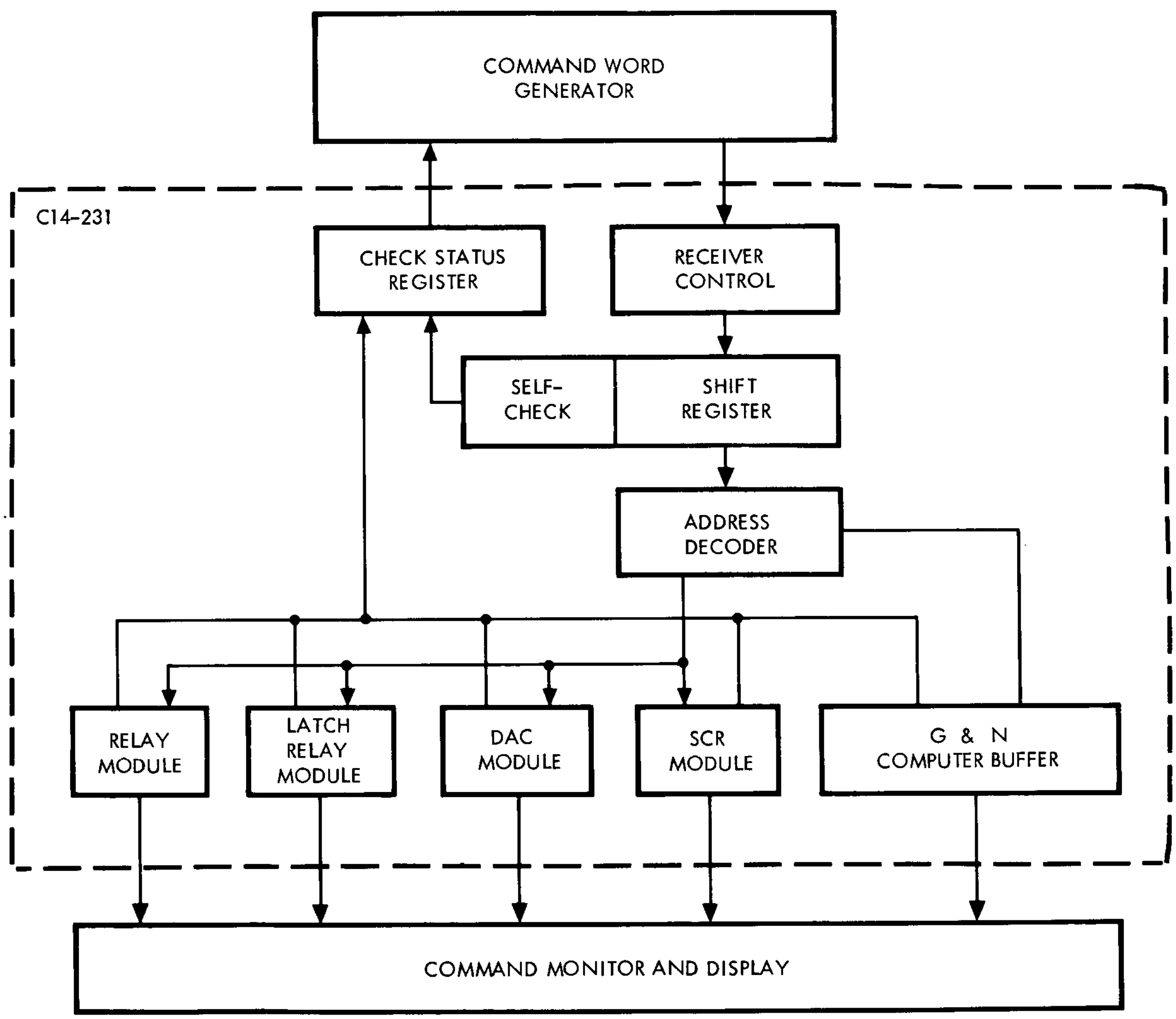

Figure 11-4. Command System Test

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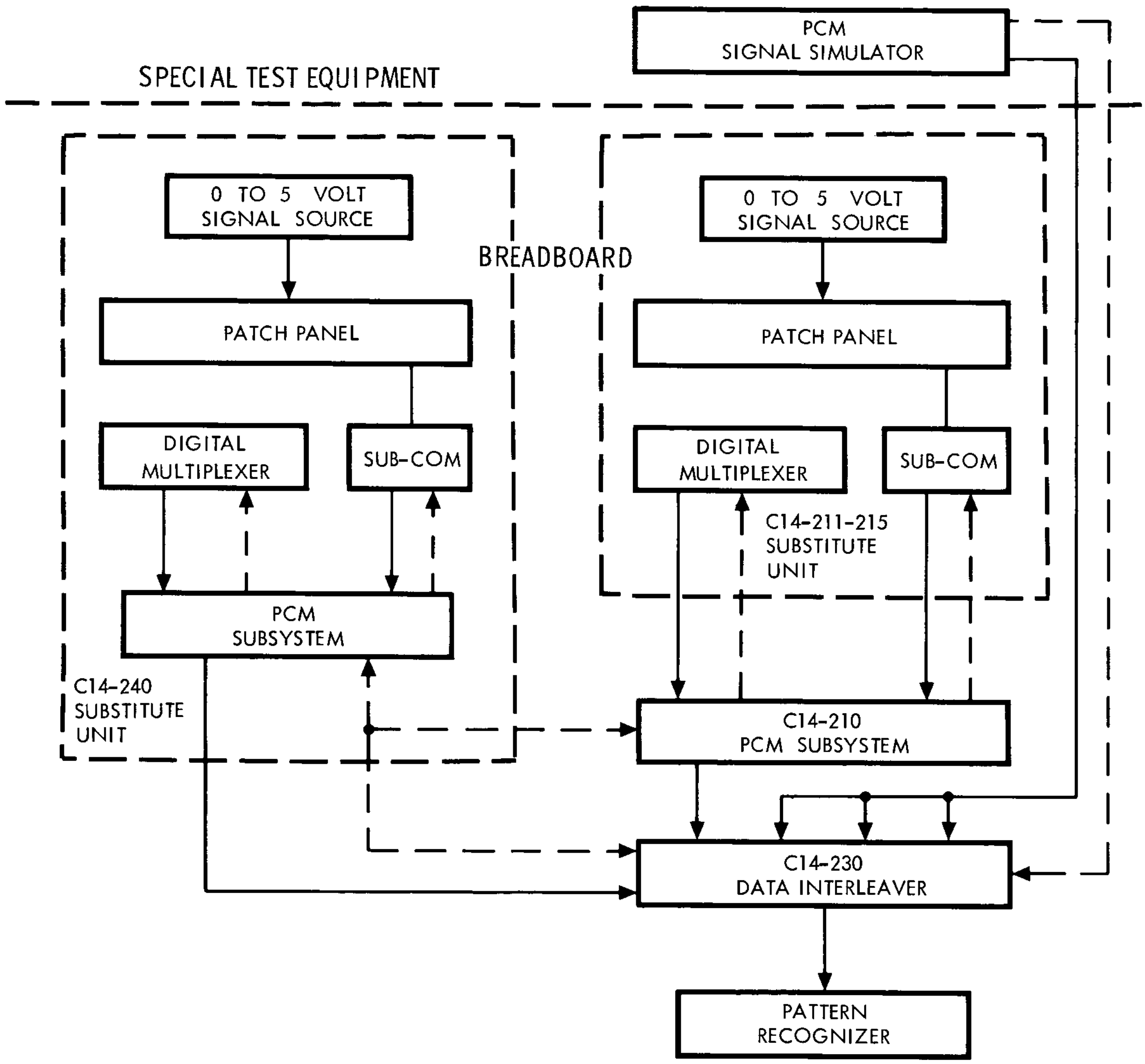

Figure 11-5. Response System Test

[redacted]

a. Functional test of the C14-210 Carry-On PCM Subsystem and the C14-211 through C14-215 Substitute Unit, when operating into the assigned channel of the interleaver

b. Functional test of the C14-240 Servicing Equipment ACE-S/C Adapter Substitute Unit, when operating into the assigned channel of the interleaver

c. Test of functional compatibility of the subcommutator's carry-on PCM subsystem

d. End-to-end performance test of the overall response data system.

11.8.2.4.2.2 Phase 2 Tests. The second phase will be the first complete checkout system test (closed loop). The equipment will be connected as shown in Figure 11-6. The test will have the following detailed objectives:

1. Integrate the components of a complete checkout system and evaluate overall system performance

2. Study system timing problems that may be encountered in component subsystem assembly

3. Study data formats and their effect on programming and logic complexity

4. Develop self-check and auto-check methods and eliminate verification simulator redundancy

5. Verify ACE system programming.

11.8.2.4.2.3 Uses of Breadboard 1 and 2. Breadboard 1 will be sent to AMR and used in conjunction with the control room. The breadboard will be used with the computer, DTVC, and monitor and control consoles. This will enable all systems to be checked under actual operating conditions (cable lengths, etc.). Breadboard 2 will remain at Downey and be used to run special developmental tests, including the following:

1. Incorporation of cordwood circuitry

2. Integration of STU and ACE

3. Testing of developmental signal conditioners

4. Special engineering tests.

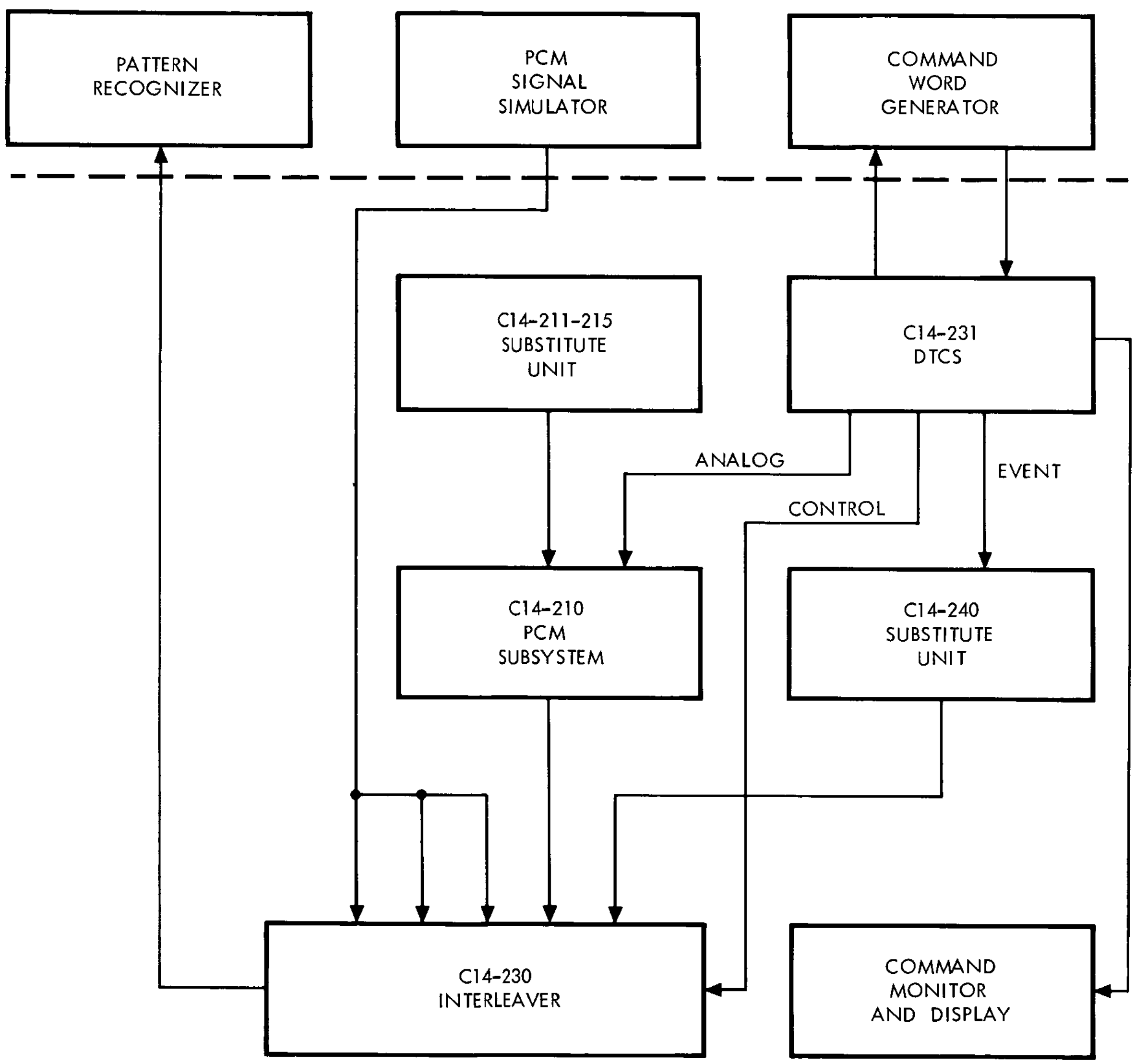

Figure 11-6. Closed-Loop Test

[redacted]

11.8.2.4.2.4 Breadboard Test Equipment. The test equipment will consist of control consoles, pattern recognizer, command word generator, output display unit, PCM signal simulator, and general purpose laboratory test equipment.

11.8.3 Test Equipment

The following list of test equipment will be required to support the testing of the carry-on GSE and for verifying and maintaining the individual subsystems.

Description	Quantity
Square wave generator, 105, Tektronix	1
Pulse generator, 212A or equivalent, Hewlett-Packard	2
Regulated power supply - variable 0-30 VDC - 20 amps	1
Digital voltmeter, V35B or equivalent, nonlinear systems	2
Multimeter, 630 or equivalent, Triplett	5
VTVM, 412A or equivalent, Hewlett-Packard	1
Differential voltmeter, 803 or equivalent, John Fluke	2
Frequency counter, 8360 or equivalent, Beckman	1
Oscilloscope, 545, Tektronix	4
Scope-mobile cart, 500/52A, Tektronix	3
10X Probe, 6022, Tektronix	4
Plug-in, C/A, Tektronix	4

[redacted]

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Description	Quantity
Plug-in, D, Tektronix	2
Plug-in, L, Tektronix	1
Impedance bridge, 250 or equivalent, Electro Sensitive Instruments	1
Resistance Decade Box, 14322 or equivalent, General Radio	1
Dual Beam, 565 or equivalent, Tektronix	1
Plug-in, 3A74 or equivalent, Tektronix	2
Oscilloscope camera, C-12, Tektronix	1

The following list of loose equipment will be required in addition to the above for the support of the PACE test program.

Description	Quantity
Vertical rack	10
Video pair cable (3 pair) 124 ohms, General cable 1695VL	2500 feet
Coaxial cable RG191V	1000 feet
Video patch cable	1
Patch cables	1 set

The development and testing of the checkout system GSE will be conducted at the Downey facility of S&ID and at the NASA facility at AMR. The facility will contain the following equipment:

Digital computer	CDC Model 160-A
Input/output typewriter	CDC Model 161
Magnetic tape units	CDC Model 163-3
Line printer	CDC Model 166-2
Auxiliary arithmetic unit	CDC Model 168

[redacted] [redacted]

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Auxiliary memory unit	CDC Model 169-1
Card read/punch unit	CDC Model 1609
Incremental plotter	CDC Model 165
PCM ground station and decommutator	
Computer input/output buffer	
Monitor and control console	
Decommutator system and MTO	
Flex-O-Writer	
Key punch	
Card to tape unit	
C/M simulator	
S/M simulator	
Carry-on interface simulator	
PCM simulator	
Command monitor and display	
Response system output display	
CRT display	

11.8.4 Test Schedules

The test program schedule for the PACE Breadboard No. 1 is shown in Figure 11-7. Breadboard No. 2 test schedule is to be established.

[redacted]

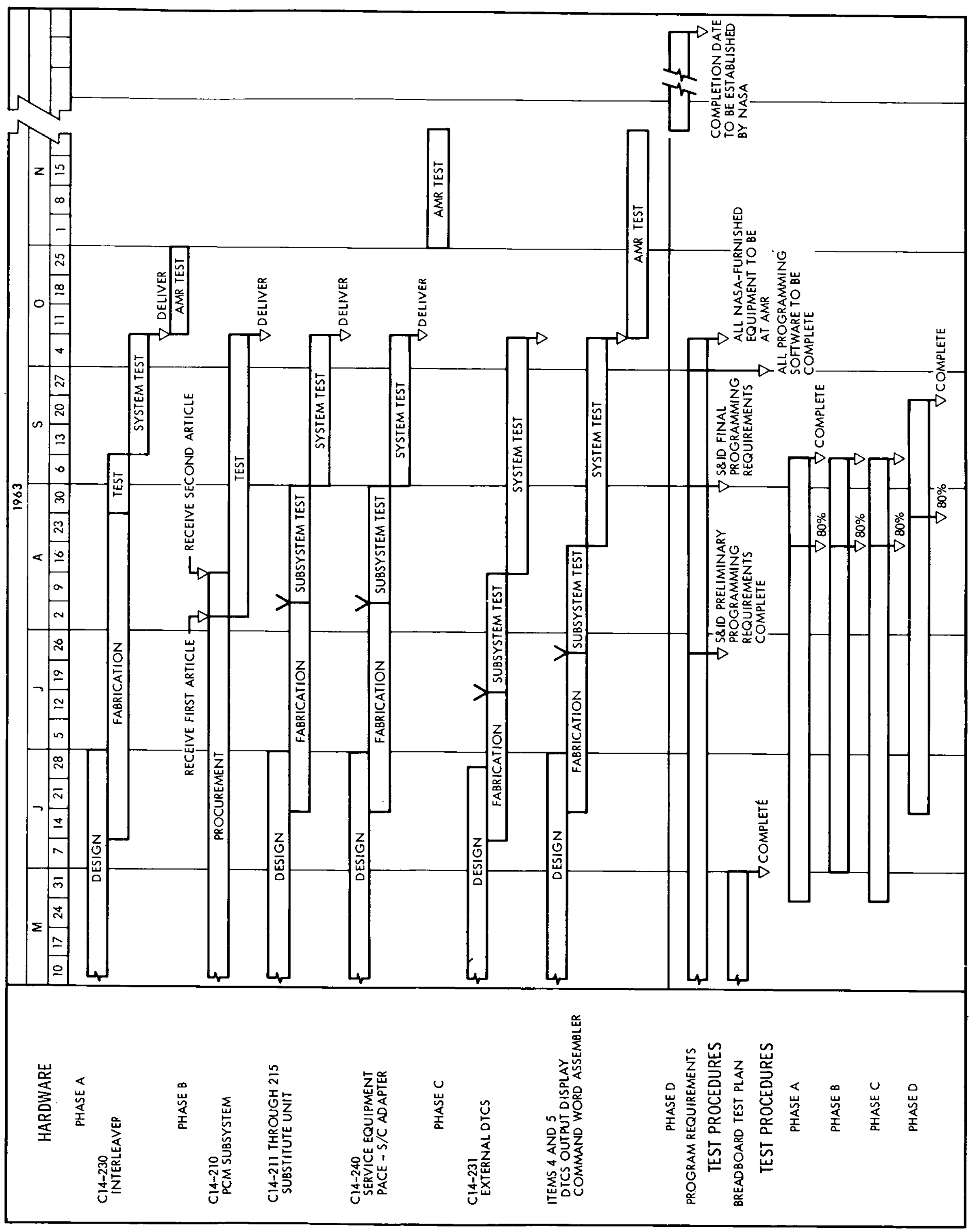

Figure 11-7. Breadboard No. 1 Test Program Schedule

12.0 STRUCTURAL TESTS*

12.1 SCOPE

The structural development and verification test program presented in this section is a planned approach to a rigorous demonstration that the structural design of the Apollo spacecraft meets or exceeds the critical limit requirements of the Apollo mission.

The scope of the program includes testing of components, subassemblies, modules, and complete airframes for the launch escape system, command module inner structure, command module heat shield, service module, spacecraft/LEM adapter, and combined modules.

The program conforms to a specific test plan logic which defines the type, nature, and time of testing needed to support the hardware and mission requirements of the airframe milestones which culminate in successful manned flight. Each test and its objective is presented in this section. Included are tests conducted by S&ID and subcontractors.

The structural tests set forth in this test plan are supplemented by tests conducted for mechanical devices, material processes and producibility, and thermal protection, and by tests on boilerplates.

12.2 STRUCTURAL DEVELOPMENT AND VERIFICATION TEST LOGIC

The basic ground rule of all testing must subscribe to the simple question, "Is it both necessary and sufficient?" To paraphrase, does the information needed require testing, and will the testing contemplated satisfy the need? With this question as a guide, the structural test program is conceived as a sequence of supporting tests leading to the successful flight qualification of the end-item spacecraft.

Test logic is based on the requirement of the program to provide mission support as well as hardware support. Each phase of the Apollo mission is considered to determine the extent that related testing will verify

*Entire section reissued

the environmental compatibility of the spacecraft structural materials and behavior under environment loads. Hardware support in testing is provided by considering each item of hardware to establish the amount of testing necessary to verify its structural capacity and margin of safety under critical load and/or maximum combined stress.

Under a mission and hardware-oriented concept, test logic contains three principle levels of testing:

Components
Subassemblies
Full-scale airframes and combined modules

Component testing begins with sample specimens of the basic spacecraft materials to establish strengths and thermal characteristics of materials. Larger configurations are then tested under simulated flight environments, using Apollo criteria of static and dynamic loads, hard vacuum, heat, cold, impact, and vibration. Off-limit tests are conducted to determine design margins of safety and ultimate material properties. Component testing also provides design parameters, such as elastic properties and material coefficients, to be used in a computer-programmed structural analysis which is a basic tool in the development of the structural system.

Subassemblies such as the rendezvous windows, launch escape tower, C/M-S/M shear-compression pads, etc., are tested to prequalify these special design items in support of the applicable airframe tests.

Airframe tests are the milestones in the program. The Apollo Test Requirements (ATR) program supports each airframe test, which in turn releases certain constraints upon the testing of the subsequent airframes and combined modules. (See hardware support test sequence chart in subsection 12. 2. 2.)

This sequential matrix of mission and hardware support testing progresses until all constraints have been lifted for the flight of Spacecraft 011.

The current program makes provision for the integrated testing of all Block I spacecraft.

12.2.1 Structural Systems Tests

The time-sequenced test logic describes the milestone support of each airframe test and traces concisely the progression of each test phase.

The structural systems test chart (Figure 12-1) indicates how the time-sequence testing of each airframe supports the ultimate goal, the earth-orbital flight of airframe 011. The boilerplate test articles are shown on the chart only to indicate their support of the overall test program.

12.2.1.1 Launch Escape Tower Tests

The launch escape tower test article is a spacecraft-configured launch escape vehicle structure which is static-tested to the critical abort loading conditions. The tests on the launch escape tower remove the constraint for the boilerplate 6 (pad abort) launch vehicle. The subsequent boilerplate launch vehicles (12, 23, and 22) are used to verify the escape vehicle structure for the launch of airframes 002 and 010.

12.2.1.2 Airframe 001 (Service Module Propulsion Test)

Airframe 001 is used for a service propulsion system static test of the service module engine and support structure. Airframe 001 supports combined module testing by lifting the constraints for the launch of airframes 009 and 011.

12.2.1.3 Airframe 002 (Maximum Q Abort Flight Test)

Airframe 002 is a maximum q abort flight test article using the command module heat shield without ablator. The command module of the test article is directly supported by the airframe 004 static test and is, therefore, constrained by this test article. The evaluation of the launch escape system of the boilerplate 22 flight article and that of the airframe 002 command module are in direct support of the flight of airframe 009.

12.2.1.4 Airframe 004 (Static Structural Test)

The Airframe 004 test is a static test of the command module, service module, and spacecraft/LEM adapter, which will be used to lift the structural constraints for the launch of airframes 009 and 011. The structural constraints will be released upon successful completion of static simulation of abort and reentry loads, parachute deployment, mortar spring rates,

[redacted]

separation of service module at maximum $q\alpha$, and C/M-S/M fairing disconnect, as well as subassembly tests of crew couch, tower ejection, and thruster structures.

12.2.1.5 Airframe 005 (Thermal, Structural, and Land Impact Test)

The Airframe 005 test is a static test of the command module for thermal, structural, and land impact evaluation. The environment proof (reentry thermal) test will be used to support, and lift the structural constraints for, the launch of Airframe 009. The land impact test evaluation will be used to lift the constraints for the launch of Airframe 011.

12.2.1.6 Airframe 006 (Acoustic and Vibration Environment Proof Tests)

The Airframe 006 test is a static acoustic and vibration environment proof test of the service module and combined command and service modules. The command module will be complete with ablative heat shield. The acoustic environment proof test will be used to support, and lift the structural constraints for, the launch of Airframe 009. The successful completion of the acoustic and vibration environment proof test will be used to support, and lift the structural constraints for, the launch of Airframe 011. Upon completion of the environment proof test, Airframe 006 becomes available for the House Spacecraft 2 test plan.

12.2.1.7 Airframe 007 (Modal, Water Impact, and Flotation Tests)

The Airframe 007 test is a static test of the launch escape vehicle, command and service modules, and spacecraft/LEM adapter for environment proof modal evaluation, and a water impact and flotation test of the command modules. The environment proof modal tests on the spacecraft will be used in supporting the combined module tests on Airframe 006. The water impact and flotation tests on the command module will be used to lift the structural constraints on the flight of Airframe 009.

12.2.1.8 Airframe 008 (Thermal-Vacuum Environment Proof Test)

The Airframe 008 test is a static thermal-vacuum environment proof test of the combined command and service modules. The command module will be complete with ablative heat shield. During the thermal-vacuum test, a cold soak thermal test will be performed on the command module structure. The cold soak test will be used to lift the structural constraints on the flight of Airframe 011.

[redacted]

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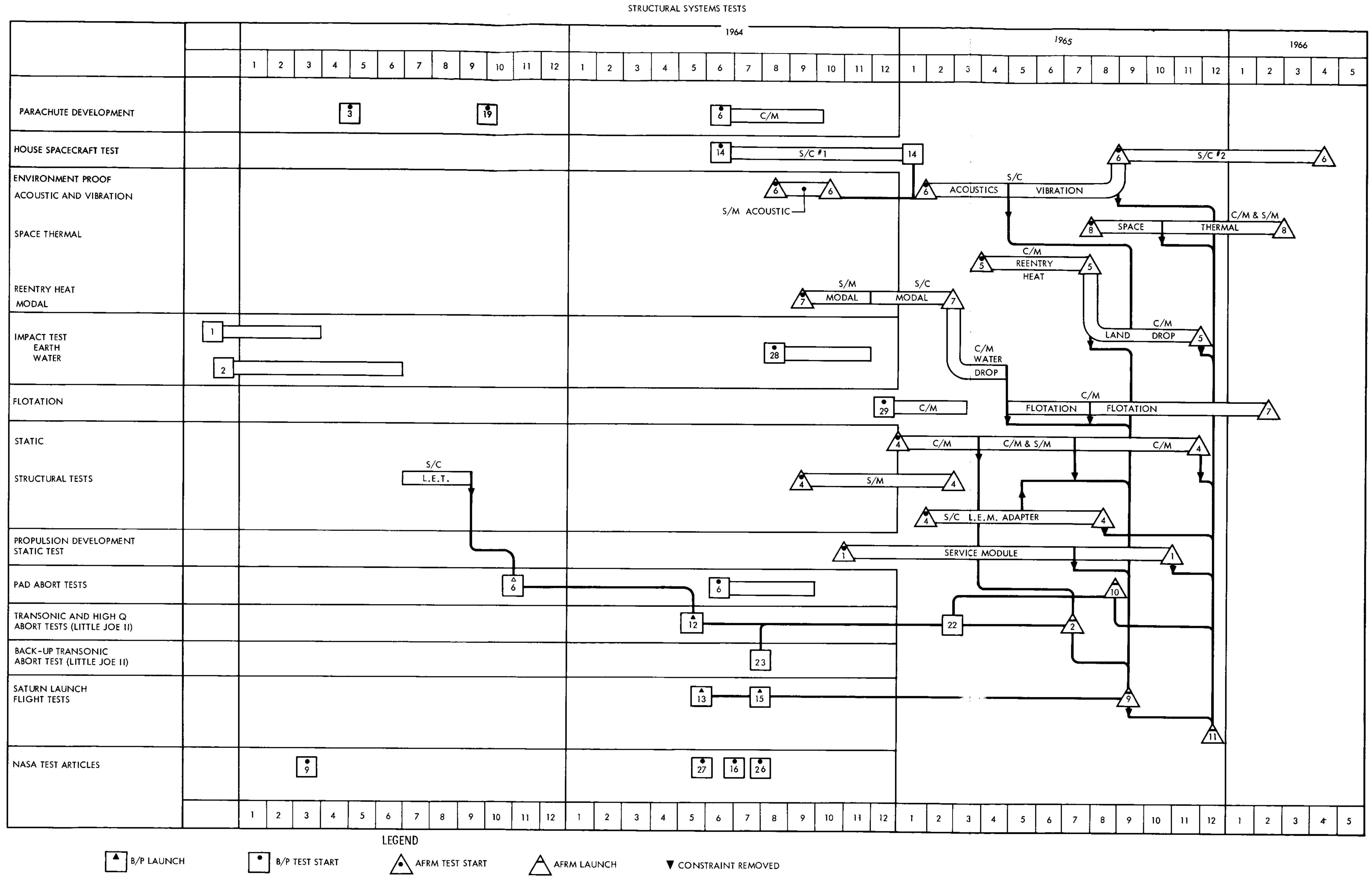

Figure 12-1. Structural Systems Tests Schedule

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12.2.1.9 Airframe 009 (Unmanned Flight)

Airframe 009 is an unmanned flight article incorporating the launch escape vehicle, command module, service module, and S-IVB adapter. The structural response of each portion of the vehicle will be evaluated under flight loads imposed during launch, boost, zero gravity, entry, water impact, and recovery. The command module thermal protective system will be evaluated under conditions of orbital entry. This test is in direct support of and releases the constraints for the launch of Airframe 011.

12.2.1.10 Airframe 010 (Pad Abort Flight Test)

Airframe 010 is a pad abort flight article consisting only of a launch escape system and a command module without ablator. The launch escape vehicle capability was demonstrated by the Boilerplate 6 launch, and it therefore supports the launch escape vehicle of Airframe 010. The verification of the launch escape vehicle and the command module under dynamic and jettison loading is in direct support of Airframe 011 (manned earth-orbital mission).

12.2.1.11 Airframe 011 (First Manned Earth-Orbital Flight)

Airframe 011 is the first manned earth-orbital flight vehicle, consisting of the launch escape vehicle, command and service modules, and spacecraft/LEM adapter. A Saturn launch vehicle will be used. The primary objectives of the preceding test program have been directed toward the verification of the spacecraft vehicle structures for the flight of this airframe.

12.2.2 Apollo Spacecraft Hardware Support Test Sequence

The hardware support test sequence chart (Figure 12-2) is an airframe oriented structural test logic chart designed to show how the scheduling of ATR tests and boilerplate tests has been planned to support the full-scale spacecraft airframe tests. The ATR program is divided into two categories: (1) those ATR and subcontractor test programs that support the full-scale spacecraft test article, and (2) those ATR tests that are performed directly upon the airframe test article.

The chart also shows the scheduling of airframe static tests and how they are integrated to support the spacecraft flight test articles. This information includes airframes supported by the static airframe tests and the dates on which particular airframe static tests are to lift the structural constraints for the specified flight test articles.

12.2.2.1 Launch Escape Tower Tests

The test article consists of a complete prototype spacecraft configured launch escape tower and skirt structural assembly.

The primary mission of the launch escape tower test is to demonstrate by static test the integrity of the structure for the pad abort and maximum q abort loading environment.

The full-scale launch escape tower static program will be prequalified by a series of ATR tests on components and subassemblies as follows: ATR 500-1 (launch escape tower attachment fitting test), ATR 501 (launch escape tower static rocket firing test) and ATR 502-2 (launch escape tower attachment fitting test).

The launch escape tower static test article will be used to mission-qualify the structure for support of Boilerplates 6 (pad abort), 12 (transonic abort), and 22 (high altitude abort), and Airframes 002, 010, 009, and 011. The static test of the launch escape tower removes the constraint on Boilerplate 6. Note that the launch escape vehicle is verified by the use of boilerplate flight test articles, and that the final verification, including any modification, is performed on Airframes 002 and 010.

12.2.2.2 AFRM 001 (Service Module Propulsion Test)

The general mission of Airframe 001 is the verification of the compatibility of the spacecraft service module propulsion system when integrated with related primary service module subsystems and operating under various conditions, including those of mission flight. The airframe static test will be used for structural support of Airframes 009, 011, 014, and 020 (spacecraft flight articles).

12.2.2.3 Airframe 002 (Maximum Q Abort Flight Test)

The spacecraft flight configuration consists of a launch escape system, command module (without ablator), and service module. A Little Joe II booster will be used.

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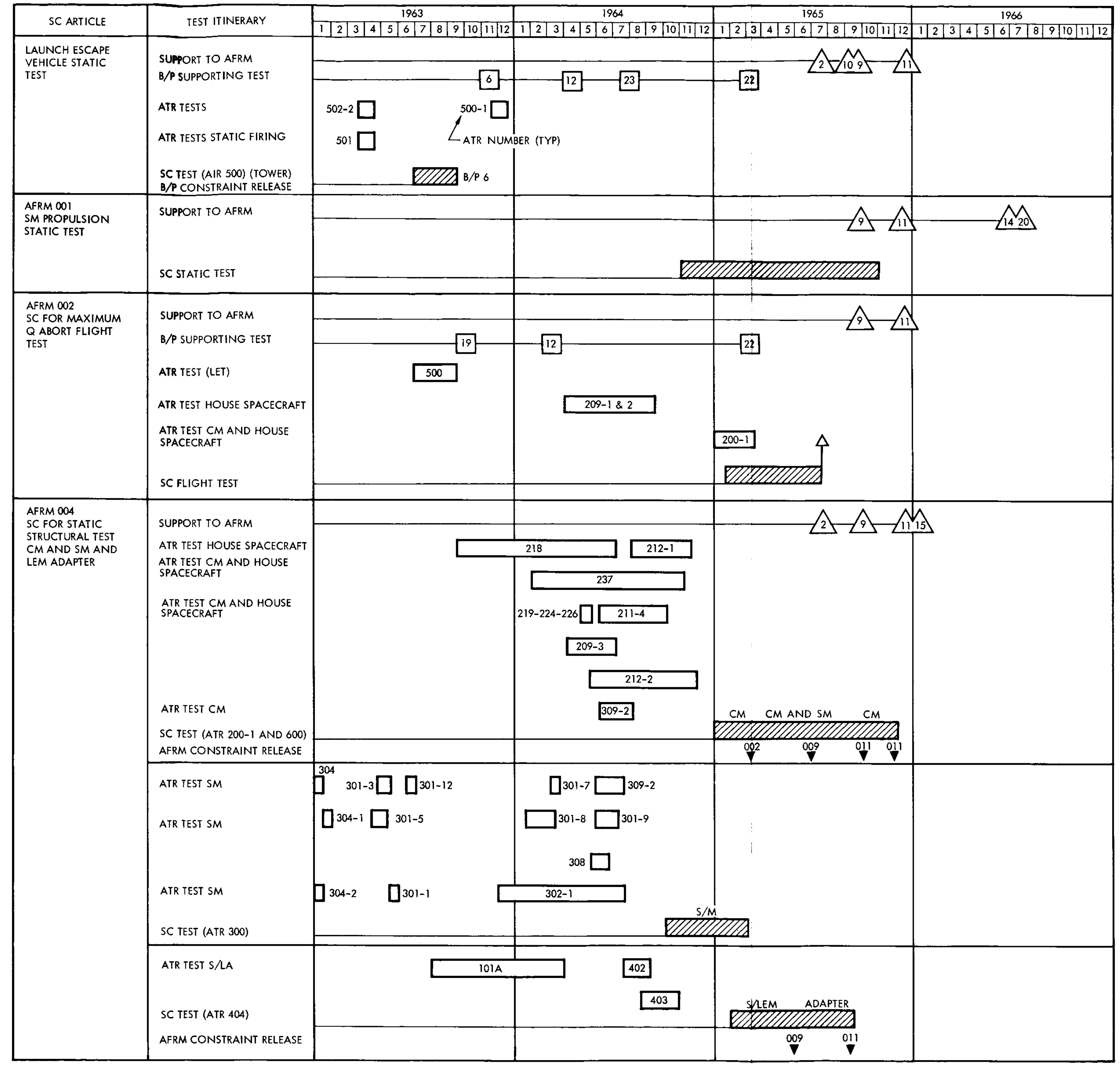

Figure 12-2. Apollo Spacecraft Hardware Support Test Sequence (Sheet 1 of 3)

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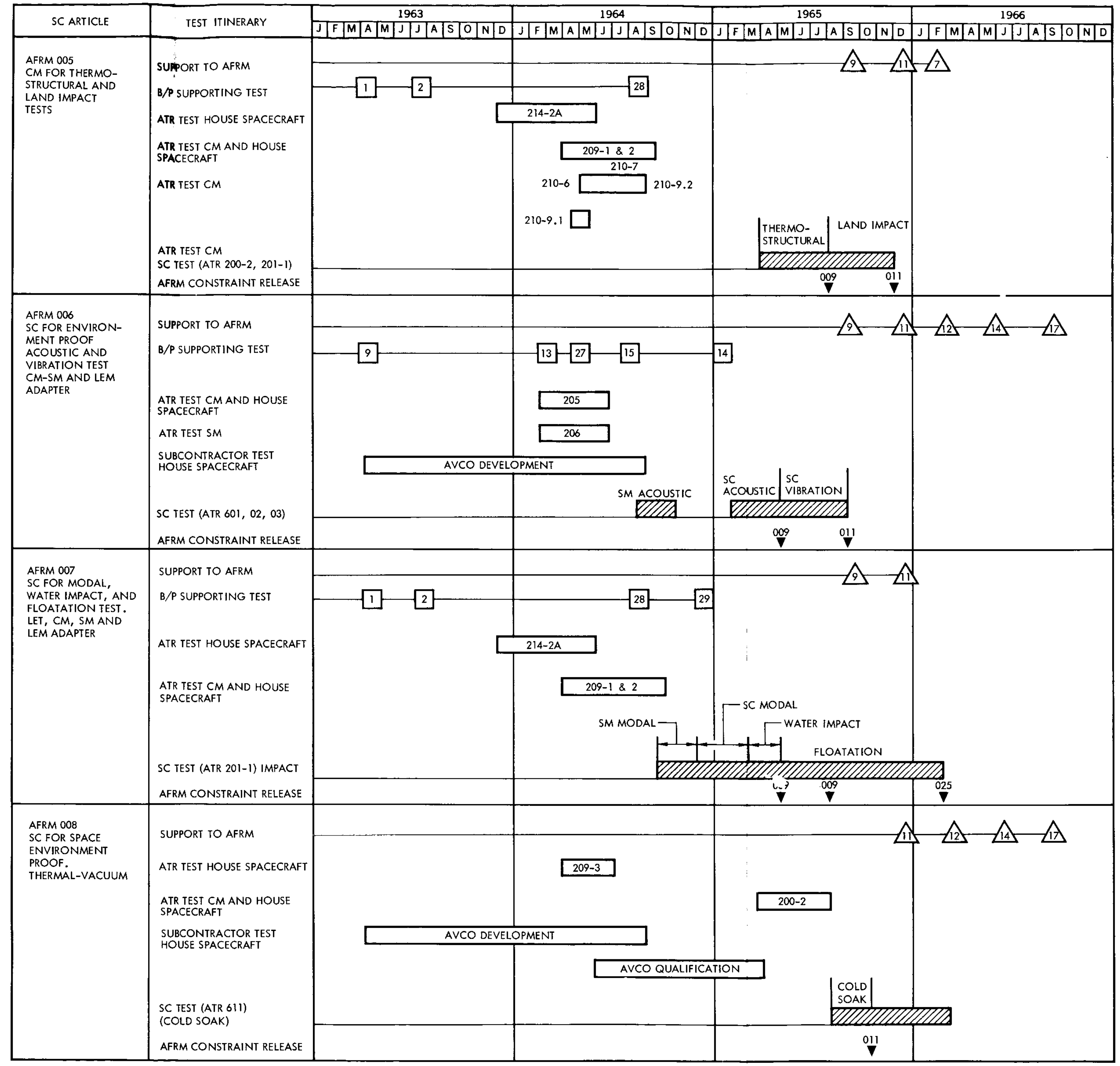

Figure 12-2. Apollo Spacecraft Hardware Support Test Sequence (Sheet 2 of 3)

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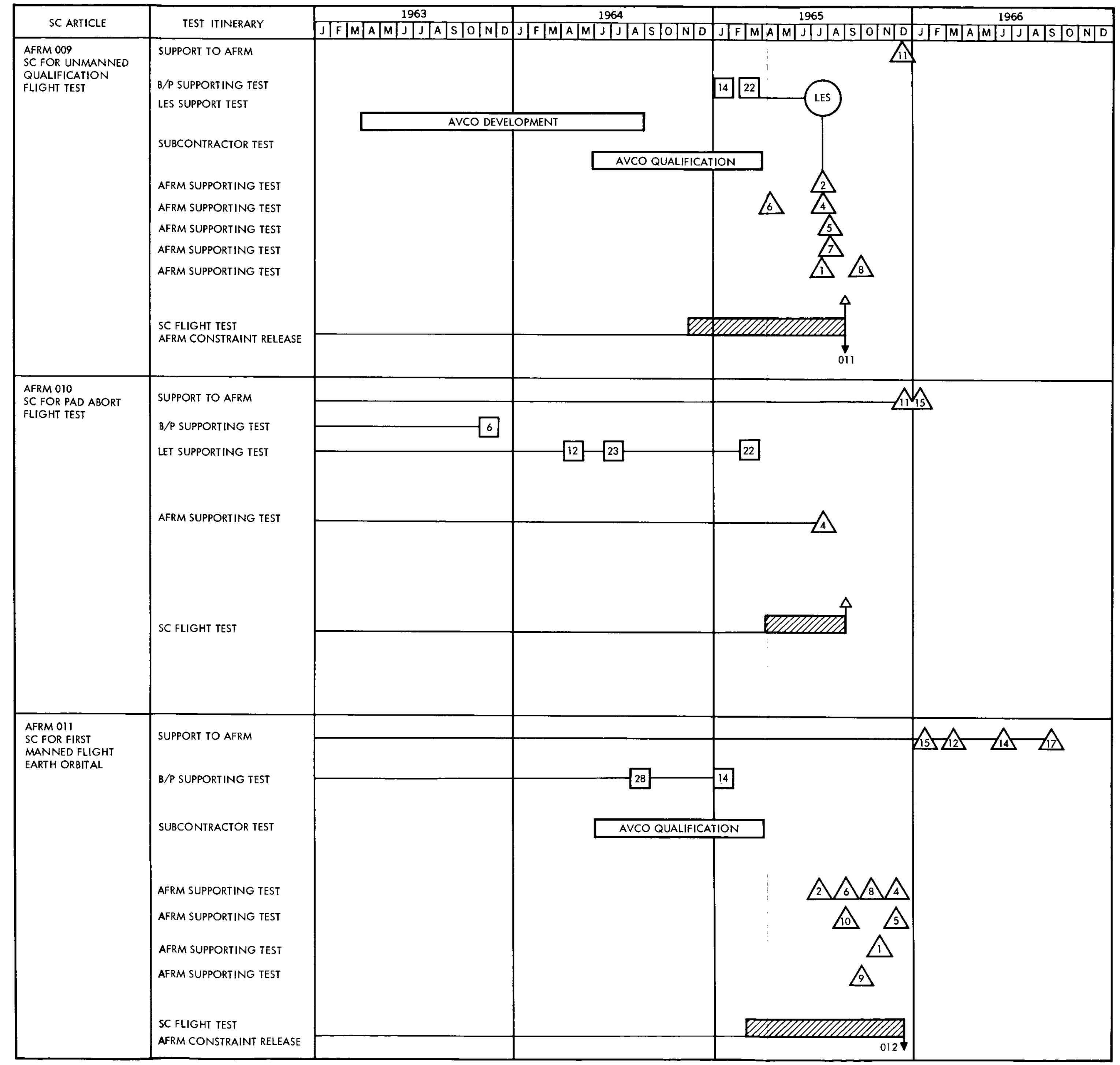

Figure 12-2. Apollo Spacecraft Hardware Support Test Sequence (Sheet 3 of 3)

[redacted]

[redacted] [redacted]

The primary mission of Airframe 002 is to qualify the structural behavior of the production command module (inner structure and heat shield) and the operational characteristics of command module systems during an abort at a high dynamic pressure in a transonic speed range.

The command module flight article will be verified by (1) boilerplate flight articles 12 and 19, and (2) ATR-209-1 and -2 (command module base section-inner and aft heat shield component test) and ATR 200-1 (command module static test of Airframe 004). The Airframe 002 flight articles will be used to mission-verify the structure for support of Airframes 009 and 011.

12.2.2.4 Airframe 004 (Static Structural Test)

The spacecraft consists of a dummy launch escape tower test fixture, command module (without ablator), service module, simulated service module adapter, and spacecraft/LEM adapter. The test program will be conducted in five structural arrangements:

Service module and simulated adapter
Command module and dummy escape tower
Command module, service module, and simulated adapter
Spacecraft/LEM adapter
Command module

The primary mission of Airframe 004 is to demonstrate the structural integrity of each vehicular component under simulated (static test) critical Apollo mission loading conditions.

The command module heat shield, which is a subsystem of the overall command module structure, will be tested with the command module inner structure under the direction of ATR 200-1 (command module static tests) and ATR 600 (combined C/M-S/M static tests).

The full-scale command module heat shield static test program will be verified by a series of ATR tests on components and subassemblies as follows: ATR 218 (brazed steel honeycomb joint tests), ATR 237 (brazed heat shield tests), ATR 212-2 (command module heat shield window panel tests), ATR 219 (crew compartment heat shield stringer assembly tests), and ATR 224 (command module crew hatch tongue and groove test).

[redacted]

[redacted]

The Full-scale command module inner structure will be verified by a series of ATR tests on components and subassemblies as follows: ATR 309-2 (bonded aluminum honeycomb joint tests), ATR 209-3 (frame and ring - crew compartment heat shield tests), ATR 212-2 (command module inner cabin and heat shield window panels and seals tests), ATR 219 (crew compartment heat shield stringer assembly tests), and ATR 209-1 and -2 (static tests of base section subassembly heat shield and aft heat shield).

The service module structure will be tested in two series of tests: ATR 300 (service propulsion system structurel stiffness evaluation and fairing static test) and ATR 600 (combined C/M-S/M static test).

The service module structure will be verified by a series of ATR tests on components and subassemblies as follows: ATR 301-3 (simulated aft bulkhead test), ATR 301-5 (radial beam test), ATR 301-12 (blind rivet joint test), ATR 304 (aft bulkhead structural component test), ATR 304-1 (aft bulkhead splice and shear panel tie test), ATR 304-2 (aft bulkhead component test), and ATR 309-2 (structural joint test). In addition, the outer shell will be verified by ATR 301-1 on a 60-degree panel, by ATR 301-7 (friction shear joint test), by ATR 301-9 (circumferential and longitudinal edge member test), and by ATR 308 (reaction control system panel test).

The pressure vessels used in the service module propulsion system will be verified for spacecraft use under the series of ATR test programs as follows: ATR 302-1 (service propulsion system pressure vessel tests), ATR 301-8 (service propulsion system main propellant tank door test), ATR 308 (service module reaction control system tank a[illegible]upport tests).

The spacecraft/LEM adapter structure will be static-tested under the direction of ATR 404.

The full-scale spacecraft/LEM adapter will be verified by a series of static tests on components as follows: ATR 402-1 (structural element thermal test), ATR 402-2 (joint test), ATR 402-3 (frame test), ATR 403-1 (access door test), ATR 403-2 (lower panel test), and ATR 101A (separation test).

The airframe 004 static test article will be used to mission-verify the structure in support of Airframes 002, 009, 011, and 015. Supplementary to the above, the static test of Airframe 004 will be used to lift the structural constraints on Airframes 002, 009, and 011.

[redacted]

12.2.2.5 Airframe 005 (Command Module Thermal, Structural, and Land Impact Test)

The spacecraft consists of the command module inner crew compartment and the heat shield substructure (without ablative material). The test program is made up of two elements: the simulation of reentry heat flux (thermal test), and the simulation of reentry earth landing (drop test).

The primary mission of Airframe 005 is to verify the structural adequacy of the command module heat shield and inner structure under reentry thermal and earth impact environment mission conditions.

The command module heat shield and inner structure will be tested simultaneously under the direction of ATR 200-2 (static thermal test) and ATR 201-1 (land drop impact test)

The full-scale command module heat shield static test program will be verified first by boilerplate drop test articles 1, 2, and 28, and second by a series of ATR tests on components and subassemblies. The ATR's are: ATR 209-1 and -2 (command module base section - inner and aft heat shield component test), ATR 226 (C/M-S/M compression pad tests), ATR 214-2A (command module heat shield flexibility tests), and the subsequent test program performed on Airframe 004 (ATR 200-1).

The full-scale command module heat shield and inner structure thermal and impact test program will be evaluated first by boilerplate drop test articles 1, 2, and 28, and second by a series of ATR tests on components and subassemblies. The ATR's are: 209-1 and -2, 226, 214-2A, 210-9.1, 210-9.2, 210-5, -6, and -7, and subsequent tests performed on Airframe 004 (ATR 200-1).

The Airframe 005 static test article will be used to verify the structure for support of Airframes 009, 011, and 007. In addition, the Airframe 005 tests will be used to lift the structural constrains on Airframes 009 and 011.

12.2.2.6 Airframe 006 (Acoustic and Vibration Environment Proof Tests)

Airframe 006 will consist of a launch escape system, command module (complete with ablative heat shield), service module, and spacecraft/LEM adapter.

The primary mission of Airframe 006 is to examine the acoustic and vibration characteristics of the spacecraft under all Apollo mission operating modes for design verification and evaluation of the structure, related systems, and equipment.

[redacted]

The command module heat shield and inner structure, together with the service module, will be tested simultaneously for vibration and acoustic environment conditions under the direction of ATR 603 (spacecraft acoustic environment proof test), ATR 602 (spacecraft modal and vibration transmissibility test), and ATR 601 (spacecraft environment vibration proof test).

Airframe 006 is also designated for the House Spacecraft 2 test program, which will follow the completion of ATR's 601, 602, and 603. The objective of the House Spacecraft 2 test program is to verify systems performance, systems integration, GSE compatibility, and in-flight maintenance capability; develop operation procedures; and verify performance to design specification, including reliability.

The full-scale command and service modules will be verified (1) by boilerplate test articles 9, 14, 27, 13, and 15, and (2) by a series of ATR component tests. These ATR tests are: ATR 205 (vibration and acoustics test on typical command module panel section), ATR 206 (vibration and acoustics test on typical service module panel section), and ATR 210-9.3 (vibration and acoustics test on typical command module inner structure). The Avco ablative heat shield development test program will contribute to the component-level verification.

The Airframe 006 static test program will be used to mission-qualify the structure for support of Airframes 009, 011, 012, 014, and 017.

12.2.2.7 Airframe 007 (Modal, Water Impact, and Flotation Tests)

Airframe 007 consists of a refurbished launch escape system, command module, and service module to be used for modal tests. The water drop impact test and flotation test will be conducted only on the command module.

The primary missions of Airframe 007 will be (1) to evaluate the basic structural vibration modes and determine vibration transmissibility characteristics, (2) to verify the structural compliance of the command module and crew support for water impact drop tests, and (3) to verify flotation characteristics, and recovery aid effectiveness under pool and sea environments.

The command module heat shield and inner structure will be tested simultaneously at water impact conditions under the direction of ATR 201-1 (earth landing - water impact tests).

The full-scale command module (inner compartment and heat shield) will be prequalified for water impact first by boilerplate test articles 1, 2, 28, and 29, and second by a series of ATR component tests. The ATR tests are: ATR 209-1 and -2 (command module base section inner and aft heat shield component test) and ATR 214-2A (command module aft heat shield flexibility test).

The service module will be tested in three modal test configurations: (1) service module only, (2) combined command module and service module, and (3) combined launch escape system (refurbished), command module, and service module. The objectives of the modal tests will be to measure the lateral bending modes, axial modes, shell and panel modes, vibration transmissibility, and service propulsion system vibration transmissibility.

The Airframe 007 static test article will be used to verify the structure for support of Airframe 009. In addition, the static water drop test and flotation test of the command module will be used to lift the structural constraints on Airframe 009.

12.2.2.8 Airframe 008 (Thermal-Vacuum Environment Proof Test)

Airframe 008 will consist of a command module (complete with the ablative heat shield), a service module, and a special base support. The three components will be assembled in a chamber capable of imposing the vacuum and thermal test conditions.

The mission of Airframe 008 will be to evaluate the flight-configured spacecraft under simulated mission environmental conditions and to verify that the spacecraft, spacecraft structure, and crew and auxiliary systems can reliably sustain, and operate in, the critical environments imposed during the actual Apollo mission.

[redacted]

Airframe 008 is scheduled for unmanned and manned environmental testing at the MSC environmental facility. The test program is designed to simulate within the test chamber the environmental conditions that the spacecraft will encounter in deep space (such as vacuum to 10^{-6} Torr, cold and darkness, solar radiation, and albedo) under variable orientations of the spacecraft with respect to the earth, moon, and sun.

The overall test plan calls for four series of tests to be conducted on Airframe 008:

1. Test series I covers those tests required subsequent to installation of the spacecraft in the environmental chamber to ensure readiness of spacecraft, chamber, and instrumentation.

2. Test series II covers those test required to evaluate and determine the ability of the spacecraft, chamber, and operating procedures to provide a safe environment and conduct safe manned testing operations.

3. Test series III covers those tests required to determine and demonstrate the manned operational suitability of the spacecraft under simulated flight environments. The constraints for Airframe 011 will be satisfied during this test series.

4. Test series IV covers those special tests required to complete a full evaluation of spacecraft operations for limited earth-orbital flight. These tests are mandatory for removal of flight constraints on Airframe 011.

During test series I and II and before test series III, a structural cold soak environment test will be conducted on the command and service modules as specified by ATR 611 (static structural cold soak test of command module).

The full-scale command module (inner compartment and heat shield) cold soak environment test program will be verified by component and ablative panel tests conducted by the subcontractor (Avco) in the ablative heat shield development and qualification test program.

Airframe 008 will be used to mission-qualify the structure for support of Airframes 011, 012, 014, and 017. The static structural cold soak environment test will be used primarily to lift the structural constraints on the flight of Airframe 011.

12.2.2.9 Airframe 009 (Unmanned Flight)

The spacecraft consists of a launch escape system, command module (complete with ablative heat shield), service module, and spacecraft/LEM adapter. A Saturn launcher vehicle will be used.

The primary mission of Airframe 009 is the verification of the spacecraft for manned earth-orbital flight. The first-order test objectives are:

1. Demonstrate the physical compatibility of the launch vehicle and production spacecraft under flight loading conditions

2. Evaluate the structural integrity of the spacecraft in suborbital flight environments, including boost, zero g, entry, water impact, and recovery

3. Determine the command module entry trajectory

4. Determine the aerodynamic stability characteristics of the command module during entry lifting

5. Evaluate the ablative thermal protective system at conditions approaching orbital entry

6. Demonstrate the satisfactory separation of the service and command modules, and of the service module and spacecraft/LEM adapter

7. Demonstrate satisfactory performance of complete Apollo recovery operations

8. Demonstrate and verify systems operations

The command module used in the flight of Airframe 009 will be verified by the following airframe static and flight test articles: Airframe 006 (vibration and acoustic environment proof tests), Airframe 002 (maximum q abort flight test), Airframe 004 (command module static structural test), Airframe 005 (reentry heat thermal test and land drop impact test), Airframe 007 (spacecraft modal, water drop impact, and flotation tests), and Airframe 008 (thermal-vacuum environment proof test). The component and ablative tests conducted by Avco in the ablative heat shield development test program will also contribute to this verification.

Airframe 009 will be used to mission-qualify, and lift the structural constraints for, Airframe 011.

12.2.2.10 Airframe 010 (Pad Abort Flight Test)

The airframe will consist of a launch escape system, a command module (without the ablative system), and a special command module-to-ground adapter.

The primary mission of Airframe 010 is to provide an early verification of the launch escape system and to verify the structural response of the command module during pad abort conditions.

The command module and launch escape system used in the pad abort flight test will be prequalified by boilerplate test articles 6, 12, 23, and 22, and by the subsequent tests performed on Airframe 004 (ATR 200-1).

Airframe 010 will be used to verify the structure in support of Airframes 011 and 015.

12.2.2.11 Airframe 011 (First Manned Earth-Orbital Flight)

The spacecraft will consist of a launch escape system, command module (complete with ablative heat shield), service module, and spacecraft/LEM adapter. A Saturn launcher vehicle will be used.

The primary mission of Airframe 011 is to demonstrate the operation and performance of the production spacecraft and spacecraft systems under manned 1-day orbital flight conditions. The first-order objectives are:

1. Demonstrate the structural integrity of the spacecraft in the orbital flight environments, including boost, earth orbit, entry, water impact, and recovery

2. Demonstrate the aerodynamic stability, trajectory, and maneuverability of the command module during lifting reentry

3. Demonstrate satisfactory operation of spacecraft systems

4. Demonstrate compatibility of manned spacecraft with GOSS, including recovery operations

5. Demonstrate satisfactory separation of service module from command module and service module from spacecraft/LEM adapter

6. Evaluate crew performance during orbital flight

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The command module used in the flight of Airframe 011 will be prequalified by the flight of Airframe 009 (unmanned suborbital flight), by the Airframe 004, 005, 007, 008, 001, 006, 010 static and flight articles, and also by the test conducted in the subcontractor's ablative heat shield test program.

Airframe 011 will be used to mission-qualify and lift the structural constraints for the flights of Airframes 012 and 015.

12.2.3 Spacecraft Test Coverage of Structural Components

The tabulations of spacecraft test coverage of structural components that are presented in this section show how the structural (ATR) tests support each spacecraft vehicle structural arrangement. The tables include each principal component and indicate what ATR test article is being used to verify its structural integrity, either as a component test, a major structural test, or as an analysis verification test.

12.2.3.1 Launch Escape System Component Tests

The launch escape tower and skirt assembly (Table 12-1) is tested under applied static design loads to verify strength and determine deflection characteristics. The escape tower and skirt are also subjected to dynamic loads, engine vibrations and acoustics, and exhaust plume blast in a static launch escape motor firing test. These tests release constraints against Boilerplate 6 and subsequent flight tests.

The primary tests are supported by component tests which serve to verify the strengths of critical joints and fittings prior to the major structural tests, and to provide preflight verification of design changes made subsequent to the major tests.

12.2.3.2 Command Module Heat Shield Tests

The structural verification of the basic heat shield shell structure (Table 12-2) is supported by subcontractor (Avco corporation) ablative panel tests, S&ID component ATR's, and full-scale Airframe 002, 004, 005, 006, 007, and 008 tests under maximum loads and critical environments.

12.2.3.2.1 Forward Compartment. The launch escape tower leg wells are component-tested under abort load conditions. Pitch engine mounts, tower leg wells, forward heat shield mounting, and ejection fittings are qualified during tests on Airframes 004 (abort), 005 (reentry — thermal) and 008 (thermal cold soak).

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12.2.3.2.2 Crew Compartment. The aft shear webs and frames are component-tested to determine the compatibility of the structural arrangement and to determine loads versus deflection and strain. The rendezvous window panel will be tested under thermal loads prior to full-scale static tests. The heat-shield-to-inner-structure slip stringers will be tested at room temperature to verify spring rate from fully extended to fully closed positions. The crew hatch window panels are component-tested under the same ATR test as the rendezvous window panel. The tongue-and-groove attach scheme of the crew hatch panels is the subject of a separate prequalifying subassembly test. These four items, plus the reaction control engine mounts, maintenance and astro-sextant door, and antenna and umbilical mounts, are also supported during the testing of Airframe 004 (reentry and abort loads), 005 (reentry heat), and 008 (cold soak). The heat shield shell closure rings at Station X_c - 23.2 and X_c - 81.0 are tested as a part of the airframe full-scale static tests under the simulated environments of reentry and abort loads, reentry heat, and thermal cold soak.

12.2.3.2.3 Aft Heat Shield. The aft heat shield without ablator is subassembly-tested at maximum q abort, 20 g reentry, and maximum heating. Load deflection data will be obtained. The tension tie bolts, compression pads, and shear/compression pads intermodular with the service module will be tested as components under static ultimate loads. Further support is provided by vibration, acoustic, and transmissibility tests, and by full-scale airframe tests. The toroidal moment tie and the C-band antenna mounting provisions are also to be evaluated during full-scale static tests.

12.2.3.3 Command Module Inner Cabin Structure Tests

The structural verification of the basic inner cabin structure (Table 12-3) is supported by subcontractor tests, S&ID component ATR's, and full-scale Airframe 002, 004, 005, 006, 007, and 008 tests under maximum loads and critical environments.

12.2.3.3.1 Forward Apex. The gussets in the forward apex area are tested under ATR 200-1 (recovery loads). The forward cylinder, forward bulkhead, and forward rings are evaluated during airframe tests on Airframe 004 (ATR 200-1, recovery), Airframe 005 (ATR 201-1, Impact), and Boilerplates 1, 2, and 28. The secondary structure undergoes limited component development-type tests while being supported by ATR 200-1 (recovery), Boilerplates 19 and 22, and ATR 201-1 (impact).

12.2.3.3.2 <u>Forward Crew Compartment</u>. The main longerons, forward sidewalls, ring frame, and 23-degree stringers are supported by ATR's 200-1 (recovery and abort) and 201-1 (impact). The attachment of the heat shield to the inner structure is component-tested under ATR 209-3 (thermal and abort). The heat-shield-to-inner-structure slip stringers are component-tested under ATR 219 for spring rate. The window panels in the forward crew compartment are component-tested under thermal, pressure, and leakage loads prior to full-scale static tests.

12.2.3.3.3 <u>Aft Crew Compartment</u>. The longerons in the aft crew compartment are tested under ATR's 200-1 (abort) and 201-1 (impact), and Boilerplate 28. The aft sidewalls and bulkhead are component-tested under ATR's 209-1 and -2 (abort, reentry, and heat).

The heat-shield-to-inner-structure frames and trusses are tested under ATR 200-1 (abort) and component-tested under ATR 209-3 (abort). Equipment attachments are tested under ATR 200-1 (abort) and ATR's 210-5, -6 and -7 (static ultimate and vibration tests).

12.2.3.3.4 <u>Additional Components</u>. The crew couch attach fittings are tested under ATR 200-1 (abort) and ATR 201-1 (impact). The external radial attenuation frames are tested under ATR 201-1 (impact) and on Boilerplate 28. The lower equipment bay is component-tested under ATR's 210-9.1, -9.2, and -9.3 (impact and dynamic loads).

12.2.3.4 Service Module Vehicle Structure Tests

The structural verification of the basic service module shell and inner structure (Table 12-4) is supported by subcontractor tests, S&ID component ATR's, and full-scale tests (Airframes 001, 004, 006, and 008) under maximum loads and critical environments.

12.2.3.4.1 <u>Outer Shell Structure</u>. The basic panel design of the outer structure is tested to determine strength properties, stress distribution, and deflection characteristics under maximum loading conditions. A series of small component tests (shear joint, circumferential and longitudinal joint, and blind rivet tests) is conducted to evaluate the panel joint capabilities. These small component tests support the overall design verification of the service module outer shell structure. The critical loading conditions are evaluated in the Airframe 004 static structural test.

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12.2.3.4.2 S/M-to-C/M Fairing. The basic C/M-to-S/M fairing structural assembly is tested in a uniform burst pressure test. The electrical umbilical structure is subjected to a series of tests to determine its functional and structural capability.

12.2.3.4.3 Inner Structure. The radial beams and aft bulkhead structures of the service module inner structure are subjected to a series of tests to demonstrate structural strength under the critical load conditions. The critical loading conditions are imposed to verify design conditions in the Airframe 004 static structural test.

12.2.3.4.4 Service Propulsion System. The structural integrity of the service propulsion engine structure is demonstrated by the structural stiffness test and the propulsion static test of Airframe 001. The structural integrity of the service propulsion tank is demonstrated under a pressure vessel test program.

12.2.3.4.5 Reaction Control System. The structural integrity of the reaction control engine support and propellant tank structure is demonstrated by a component test of the structure.

12.2.3.5 Spacecraft/LEM Adapater

The structural verification of the basic spacecraft/LEM adapter shell structure (Table 12-5) is supported by S&ID component ATR test and a full-scale test of Airframe 004. In addition, Airframes 006 and 008 are used to demonstrate the critical environmental conditions.

12.2.3.5.1 Basic Shell. A typical LEM attachment panel with LEM fittings is tested under inertia and uniform compression loads to simulate the LEM/vehicle interaction loading on the panel. A typical panel of the LEM structure incorporating the access door installation is tested for structural verification. The overall shell structure is evaluated in the full-scale static test program.

12.2.3.5.2 Frames. Component assemblies of two major ring frames, the aft ring frame and LEM attachment frame, are subjected to a combined binding and axial load test to verify the structural integrity of the design. The overall structural capability of the ring frames will be evaluated in the full-scale static test article.

12.2.3.5.3 Joints and Splices. All of the major joints and splices of the LEM adapter are static-tested in component tests and tests of the service-module-to-LEM adapter splice, the longitudinal separation joint, and the splice at X_a 584.7 (LEM adapter splice).

12.2.4 Apollo Spacecraft Tests Versus Mission Environment Support

The structural test logic was established on the basis of verifying the structural integrity of the spacecraft by simulating the critical mission environment conditions in a structural test program.

This section presents a study matrix of the critical Apollo mission environments and describes how each spacecraft structural test program supports the relevant Apollo mission phases. Thus, for each mission phase from launch to earth landing, including three potential abort modes, tests are listed in terms of the applicable environmental conditions. The supporting mission environment tests are listed as major airframe tests, related component and subassembly tests, and subcontractor development and verification tests. Design verification and analysis verification tests have been included in the matrix tables to show how these tests are integrated into the mission environment phase and how they support the structural design analysis of the vehicle for the overall Apollo mission requirements.

The mission support tables are presented by test vehicle in the following sequence: launch escape vehicle (Table 12-6), command module heat shield vehicle (Table 12-7), command module inner cabin vehicle (Table 12-8), service module vehicle (Table 12-9), and LEM adapter vehicle (Table 12-10). The tables indicate only the significant mission conditions to which the vehicles will be subjected.

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Table 12-1. Launch Escape System Test Coverage

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
FORWARD STRUCTURE			
Pitch control motor		B-6, 12, 22, 23, AFRM 2, 10	
Ballast enclosure		B-6, 12, 22, 23, AFRM 2, 10	
Nose cone		B-6, 12, 22, 23	
STRUCTURAL SKIRT ASSEMBLY			
Skirt assembly	ATR 501 (static firing) ATR 500 (static load test) ATR 500-1 (fitting test) ATR 102-A (fitting test)	B-6, 12, 22, 23, AFRM 2, 10	LR 6790 (tube cluster test)
LES BODY INTERFACE JOINTS			
C/M to tower	ATR 211-4 (fitting test)	B-6, 12, 22, 23, AFRM 2, 10	
Tower to skirt	ATR 502-2 (fitting test)	B-6, 12, 22, 23, AFRM 2, 10	
Skirt to launch escape motor	ATR 500 (static load test)	B-6, 12, 22, 23, AFRM 2, 10	
Launch escape motor to jettison motor		B-6, 12, 22, 23, AFRM 2, 10	
Jettison motor to pitch motor		B-6, 12, 22, 23, AFRM 2, 10	
Pitch motor to ballast enclosure		B-6, 12, 22, 23, AFRM 2, 10	

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Table 12-2. Command Module Heat Shield Component Test Coverage

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
FORWARD COMPARTMENT			
Basic shell		ATR 200-1 (reentry, abort load) ATR 611 (thermal cold soak) ATR 200-2 (reentry heat) ATR 601, ATR 602, ATR 603 } launch and reentry, vibration, acoustic, and modal response	Avco qualification tests ATR 218 (honeycomb sandwich joint) ATR 237 (sandwich repair) ATR 214 (instability) ATR 205 & 6 (typical panel vibration) ATR 222 (sandwich bond)
Tower leg well	ATR 211-4 (abort loads)	ATR 200-1, ATR 200-2, ATR 611 } above	Avco qualification tests
Pitch engine support		ATR 200-1 (20,000-ft abort)	
Ejection fittings		ATR 200-1 (forward heat shield thrusters)	
Forward heat shield support		ATR 200-1 (reentry, abort) ATR 611 (thermal cold soak)	

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Table 12-2. Command Module Heat Shield Component Test Coverage (Cont)

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
CREW COMPARTMENT			
Basic shell		(See Basic Shell in Forward Compartment section above)	(See Basic Shell in Forward Compartment section above)
Aft shear web and frames (X_c = 43)	ATR 209-3 (thermal, abort)	ATR 200-1 (reentry, abort loads) ATR 200-3 (reentry heat) ATR 611 (thermal cold soak)	Avco development and qualification tests
Latching mechanisms (mechanical systems section)	ATR 118-1 (astro-sextant) ATR 116-1 (outer mechanism) ATR 116-2 (outer crew latch)	ATR 200-1 ATR 200-2 ATR 611 ATR 601, 602, 603 (vibration and acoustic)	
Rendezvous window panel	ATR 212-2 (pressure, heat)	ATR 200-1, 200-2, 611	
RCS engine supports		ATR 200-1, 200-2	
Stringers	ATR 219 (spring rate)	ATR 200-1, 200-2, 611, 601, 602, 603	

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Table 12-2. Command Module Heat Shield Component Test Coverage (Cont)

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
CREW COMPARTMENT (Cont)			
Crew hatch windows	ATR 212-2 (pressure, heat) ATR 224 (tongue and groove)	ATR 200-1 (reentry, abort) ATR 611 (thermal cold soak)	Avco qualification tests
Maintenance doors		ATR 200-1, 200-2, 611, 601, 603	Avco development and qualification tests
Astro-sextant door		ATR 200-1, 611, 601-2-3	Avco development and qualification tests
Antenna support		ATR 200-1, 611, 601-2-3	Avco development and qualification tests
Umbilical support		ATR 300, 600	Avco development and qualification tests
Ring (X_c = 23.2)		ATR 200-1 (reentry, abort) ATR 200-2 (reentry, heat) ATR 611 (thermal cold soak) ATR 209-1 (reentry heat)	Avco development and qualification tests

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Table 12-2. Command Module Heat Shield Component Test Coverage (Cont)

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
CREW COMPARTMENT (Cont)			
Ring (X_c = 81.0)		ATR 200-1, ATR 200-2, ATR 611 — see above	Avo development and qualification tests
AFT HEAT SHIELD			
Basic shell	ATR 209-1 (reentry heat, abort) ATR 201-1 (land-water drop)	ATR 200-1 (reentry, abort) ATR 200-2 (reentry heat) ATR 600 (launch, boost, abort) ATR 601, ATR 602, ATR 603 — launch and reentry, vibration, acoustic, and modal response ATR 214-2A (fiber-glass static)	Avco development and qualification tests
Ring (X_c = 10)	ATR 209-1 (reentry heat, abort)	ATR 200-1, ATR 200-2, ATR 200-3, ATR 600, ATR 611 — see above	Avco development and qualification tests

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Table 12-2. Command Module Heat Shield Component Test Coverage (Cont)

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
AFT HEAT SHIELD (Cont)			
Tension tie	ATR 226 (static ultimate)	ATR 209-1, ATR 600 — see above	Avco development and qualification tests
Compression and shear/compression pads	ATR 226 (static ultimate)	ATR 600 ATR 209-1	Avco development and qualification tests
Toroidal moment tie		ATR 611	Avco development and qualification tests
C-band antenna		ATR 611	Avco development and qualification tests
Ring (X_c = 23.2)		ATR 209-1 (reentry heat) ATR 200-1 (reentry, abort) ATR 200-2 (reentry heat) ATR 611 (thermal cold soak)	Avco development and qualification tests

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Table 12-3. Command Module Inner Structure Components Test Coverage (Cont)

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
SECONDARY FORWARD APEX AREA (Cont)			
Equipment attachment		ATR 200-1 (recovery, abort), ATR 201-1 (impact)	ATR 309-2 (honeycomb joints)
LES-to-inner-structure attachment	ATR 211-4 (abort)	ATR 200-1 (recovery)	
PRIMARY FORWARD CREW COMPARTMENT			
Main longerons 1 & 2	ATR 102 (development)	ATR 200-1 (abort), ATR 201-1 (impact)	
Main longerons 2 & 4	ATR 102 (development)	ATR 200-1 (abort), ATR 201-1 (impact)	
Forward sidewalls		ATR 200-1 (abort, recovery), 201-1 (impact)	ATR's 205 & 206 (vibration), ATR's 214-2B & -2E (criteria)
Ring frame $X_c = 42$		ATR 200-1 (abort, recovery), 201-1 (impact)	
23° stringers		ATR 200-1 (abort, recovery), 201-1 (impact)	
Heat-shield-to-inner-structure stringer attachment	ATR 219 (spring rate)	ATR 200-1 (abort), ATR 611 (cold soak)	

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Table 12-3. Command Module Inner Structure Components Test Coverage (Cont)

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
PRIMARY FORWARD CREW COMPARTMENT (Cont)			
Circumferential heat-shield-to-inner-structure attachment	ATR 209-3 (thermal, abort)	ATR 200-1 (abort), ATR 201-1 (impact)	
SECONDARY FORWARD CREW COMPARTMENT			
Main match door		ATR 200-1 (pressure)	
Main hatch window	ATR 212-2 (pressure, heat, leakage)	ATR 200-1 (pressure)	
Side window	ATR 212-2 (pressure, heat, leakage)	ATR 200-1 (pressure)	
Rendezvous window	ATR 212-2 (pressure, heat, leakage)	ATR 200-1 (pressure)	
Astro-sextant & telescope frame		ATR 200-1 (pressure)	
Equipment attachment		ATR 200-1 (abort), ATR 201-1 (impact)	ATR 309-2 (honeycomb joints)
PRIMARY AFT CREW COMPARTMENT			
Main longeron 1		ATR 200-1 (abort), ATR 600 (launch), ATR 201-1 (impact)	
Aft longerons 1 & 5		ATR 600 (launch)	
Main longeron 2		ATR 200-1 (abort)	
Aft longeron 2		ATR 600 (launch)	

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Table 12-3. Command Module Inner Structure Components Test Coverage (Cont)

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
PRIMARY AFT CREW COMPARTMENT (Cont)			
Main longeron 3		ATR 200-1 (abort)	
Aft longeron 3			
Main longeron 4		ATR 200-1 (abort)	
Aft longeron 4		ATR 600 (launch	
Aft sidewall	ATR's 209-1 & -2 (abort, reentry, & heat)	ATR 200-1 (abort, reentry, pressure), ATR 201-1, B-28 (impact)	
Aft bulkhead	ATR's 209-1 & -2 (abort, reentry, & heat)	ATR 200-1 (abort, reentry, pressure), ATR 201-1, B-28 (impact)	ATR 214-2B, -2E (criteria)
SECONDARY AFT CREW COMPARTMENT			
Heat-shield-to-inner-structure frames & trusses	ATR 209-3 (abort)	ATR 200-1 (abort), ATR 611 (cold soak)	
Equipment attachments	ATR's 210-5, -6, -7, & -9 (static ultimate vibration)	ATR 200-1 (abort), ATR 201-1 (impact)	ATR 309-2 (honeycomb joints)
EQUIPMENT SUPPORT			
Crew couch fittings		ATR 200-1 (abort), ATR 201-1 (impact)	

[redacted]

Table 12-3. Command Module Inner Structure Components Test Coverage (Cont)

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
EQUIPMENT SUPPORT (Cont)			
External radial attenuation frames Right-hand equipment bay Left-hand equipment bay Forward equipment bay Main display console Lower equipment bay	ATR's 210-9.1, -9.2, -9.3 (static ultimate)	ATR 201-1 (impact), B-28	

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Table 12-4. Service Module Component Test Coverage

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
OUTER STRUCTURE			
Basic panel	ATR 301-1 (panel tests)	ATR 600 (combined module test)	ATR 301-7 (shear joint test)
Panel edge member		ATR 600 (combined module test)	ATR 301-9 (circumferential and longitudinal joint test)
Doors & cutouts		ATR 600 (combined module test)	ATR 301-12 (blind rivet test)
S/M-TO-C/M FAIRING			
Basic panel	ATR 300 (fairing static test)	ATR 600 (combined module test)	
Seal	ATR 300 (fairing static test)		
Umbilical doors	ATR 300 (fairing static test)		
INNER STRUCTURE			
Radial beam	ATR 301-5 (radial shear web test)	ATR 600 (combined module test)	
Forward bulkhead		ATR 600 (combined module test)	
Aft bulkhead	ATR 304 (aft bulkhead test) ATR 301-3 (simulated aft bulkhead test) ATR 304-1 (bulkhead splice and shear test) ATR 304-2 (bulkhead component test)	ATR 600 (combined module test)	ATR 309-2 (joint test)

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Table 12-4. Service Module Component Test Coverage (Cont)

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
INNER STRUCTURE (Cont)			
Equipment bay		ATR 600 (combined module test)	
Inner web		ATR 600 (combined module test)	
SERVICE PROPULSION SYSTEM			
Engine support	ATR 300 (SPS structural stiffness)	ATR 600 (combined module test) AFRM 001 (propulsion static test)	
Propulsion tanks	ATR 302-1 (SPS pressure vessels) ATR 301-8 (SPS main tank door test)	AFRM 001 (propulsion static test)	
REACTION CONTROL SYSTEM			
Engine support	ATR 308 (RCS engine support)		
Propellant tank	ATR 308 (tank support)		

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Table 12-5. Spacecraft/LEM Adapter Components Test Coverage

Structural Component	Component Test	Major Structural Test	Analysis Verification Test
BASIC SHELL			
Quarter panel	ATR 403-2 (lower panel test)	ATR 404 (LEM adapter static test)	ATR 402-1 (LEM adapter structural element thermal test)
Access doors & cutouts	ATR 403-1 (access door panel test)		
FRAMES			
Aft frame LEM attachment frame	ATR 402-3 (structural element test)	ATR 404 (LEM adapter static test)	
JOINTS AND FITTINGS			
Forward interface joint Aft interface joint Splice at separation plane	ATR 402-2 (structural element joint test)	ATR 404 (LEM adapter static test)	

[redacted]

Table 12-6. Launch Escape System Tests by Mission Phase

Mission Phase Environment Conditions	Launch and Boost	Pad Abort	Maximum Q Abort	High Altitude Abort	Design Verification	Analysis Verification
Thermal	B-13 (launch environment) B-15 (launch environment) AFRM002 (maximum q abort) AFRM010 (pad abort) AFRM009 (suborbital unmanned qualification)	B-6 (pad abort) AFRM010 (pad abort) ATR501 (static rocket firing)	B-12 (transonic abort B-23 (backup transonic abort AFRM002 (high q abort)	B-22(hi altitude abort)	ATR 502-2 (launch escape tower skirt fitting)	
Aerodynamic pressure	B-13 (launch environment) B-15 (launch environment) AFRM002 (Maximum q abort) AFRM010 (pad abort) AFRM009 (suborbital unmanned qualification)	ATR500 (launch escape tower static test) B-6 (pad abort) AFRM010 (pad abort) ATR501 (static rocket firing)	ATR500 (launch escape tower static test) B-12 (transonic abort) B-23 (transonic abort) AFRM002 (high q abort)	ATR500 (launch escape tower static test) B-22(hi altitude abort)	ATR 500-1 (launch escape tower attachment fitting) ATR 502-2 (launch escape tower skirt fitting)	LR 6970 (tower tube cluster) LR 7099 (weld joint test)
Vibration	B-13 (launch environment) B-15 (launch environment) AFRM002, 010, 009 AFRM006 (ATR 601, 602, 603)	B-6 (pad abort) AFRM006 (ATR 601, 602, 603) AFRM007 (modal) AFRM010 (pad abort) ATR501 (static rocket firing)	B-12, 23 (transonic abort) AFRM006 (ATR 601, 602, 603) AFRM007 (modal) AFRM009 (sub-orbital) AFRM002 (high q abort)	B-22 (hi altitude abort) AFRM006 (ATR 601, 602, 603) AFRM007 (modal) AFRM009 (sub-orbital)		
Inertia g	B-13, B-15 AFRM002, 010, 009	B-6 AFRM009, 010	B-12, 23 AFRM002, 009	B-22 AFRM009		

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Table 12-7. Command Module Heat Shield Tests by Mission Phase

Mission Phase Environment Conditions	Launch and Boost	Pad Abort	Maximum Q Abort	High Altitude Abort	Earth Orbit	Translunar Coast Random Drift Orientation
Thermal	AFRM002 (maximum q abort) AFRM009 (suborbital qualification) Avco qualification tests	AFRM010 (pad abort)	AFRM002 (high q abort)		AFRM008 (ATR 611)(cold soak) AFRM009 (suborbital) Avco qualification tests	AFRM008 (ATR 611)(cold soak) Avco qualification tests
Aerodynamic pressure	AFRM002 (maximum q abort) AFRM009 (suborbital qualification ATR 226 (shear pad and tension tie) Avco qualification tests	AFRM010 (pad abort)	AFRM004 (ATR 200-1)(C/M static) AFRM002 (high q abort) ATR 209-2 (aft heat shield static	AFRM004 (ATR 200-1)(C/M static) ATR 212-2 (heat shield window tests) ATR 209-3 (heat shield frame & ring) ATR 211-4 (forward heat shield fitting)	AFRM009 (suborbital)	No requirement
Vibration	AFRM002, 006, 009, and Avco Avco qualification tests ATR 601 (S/C vibration proof - AFRM 006) ATR 602 (S/C vibration, transmissibility - AFRM 006) ATR 603 (S/C acoustic proof - AFRM 006)	AFRM010 (pad abort) AFRM006 (acoustics, vibration - ATR 601, 602, 603)	AFRM002 (high q abort) AFRM006 (acoustics, vibration - ATR 601, 602, 603)	AFRM006 (acoustic, vibration - ATR 601, 602, 603)	AFRM009 (suborbital qualification) AFRM006 (acoustic, vibration - ATR 601, 602, 603)	AFRM006 (acoustic, vibration - ATR 601, 602, 603) Avco qualification tests
Inertia g	AFRM004 (ATR 600) (combined module static test) AFRM002 (maximum q abort) AFRM009 (suborbital qualification)	AFRM010 (pad abort)	AFRM002 (high q abort) AFRM004 (ATR 600) combined module test	AFRM004 (ATR 200-1) (C/M static)	AFRM009 (suborbital qualification)	
Impact g	Booster separation only	No requirement	No requirement	No requirement	No requirement	LEM docking only

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Table 12-7. Command Module Heat Shield Tests by Mission Phase (Cont)

Mission Phase Environment Conditions	Lunar Orbit	Transearth Coast	Reentry	Earth Landing		Design Verification	Analysis Verification
				Land	Water		
Thermal	AFRM008 (ATR 611) (cold soak) Avco qualification tests	AFRM008 (ATR 611) (cold soak) Avco qualification tests	AFRM005 (ATR 200-2) (static thermal) AFRM009 (suborbital qualification) ATR 209-1, -2 (aft heat shield static) ATR 212-2 (window tests) Avco qualification tests			ATR 218 (honeycomb sandwich joint) ATR 237 (honeycomb sandwich repair) Avco development tests	ATR 216-2 ATR 208-2.2, -2.1 Avco development tests
Aerodynamic pressure	No requirement	No requirement	AFRM009 (suborbital qualification) ATR 209-1, -2 (aft heatshield static) AFRM004 (ATR 200-1) (C/M static) ATR 212-2 (window test) Avco qualification tests	No requirement		ATR 218 (honeycomb sandwich joint) ATR 237 (honeycomb sandwich repair) ATR 219 (heat shield stringer) ATR 224 (hatch tongue & groove) Avco development tests	ATR 214-2A (aft heat shield load deflection) ATR 220 (steel honeycomb core foundation modules) ATR 214-2B (instability of sandwich cylinders) ATR 214-2E (instability of sandwich cones)
Vibration	AFRM006 (acoustic, vibration - ATR 601, 602, 603) Avco qualification tests	AFRM006 (acoustic, vibration - ATR 601, 602, 603) Avco qualification tests	AFRM009 (suborbital qualification) AFRM006 (acoustic, vibration - ATR 601, 602, 603) Avco qualification tests	No requirement		ATR 205 (vibration & acoustic, typical panel) ATR 206 (sonic vibration, typical panel) Avco development tests	Avco development & qualification tests
Inertia g			AFRM004 (ATR 200-1) (C/M static) ATR 209-1, -2 (aft heat shield static)				
Impact g	LEM docking only	No requirement	No requirement	AFRM005 (ATR 201-1) (drop test)	AFRM007 (ATR 201-1) (drop test)	B-1 & -2 (aft heat shield) ATR 213 (meteoroid impact)	

Table 12-8. Command Module Inner Structure Tests by Mission Phase

Mission Phase Environment Condition	Launch and Boost	Pad Abort	Maximum Q Abort	High Altitude Abort	Earth Orbit	Translunar Coast Random Drift Orientation
Thermal	AFRM002 (maximum q abort) AFRM009 (suborbital qualification)	AFRM010 (pad abort)	AFRM002 (high q abort)		AFRM008 (ATR 611) (cold soak)	AFRM008 (ATR 611) (cold soak)
Aerodynamic pressure	AFRM002 (maximum q abort) AFRM009 (suborbital qualification)	AFRM010 (pad abort)	AFRM004 (ATR 200-1) (C/M static) AFRM002 (high q abort)	AFRM004 (ATR 200-1) (C/M static) ATR 212-2 (heat shield window tests) ATR 209-3 (heat shield frame & ring) ATR 211-4 (forward heat shield fitting)	AFRM-009 (suborbital qualification)	No requirements
Vibration	AFRM002,006,009 ATR 601 (S/C vibration proof) (006) ATR 602 (S/C vibration transmissibility) (006) ATR 603 (S/C acoustic proof) (006)	AFRM010 (pad abort) AFRM 006 (acoustic, vibration-ATR 601, 602,603)	AFRM002 (high q abort) AFRM 006 (acoustic, vibration-ATR 601,602, 603)	AFRM006 (acoustic, vibration-ATR 601,602,603)	AFRM009 (suborbital qualification) AFRM006 (acoustic, vibration-ATR 601,602, 603)	AFRM006 (acoustic, vibration-ATR 601, 602,603)
Inertia g	AFRM004 (ATR 600-combined module static test) AFRM002 (maximum q abort) AFRM009 (suborbital qualification)	AFRM010 (pad abort)	AFRM002 (high q abort) AFRM004 (ATR 600) (combined module test)	AFRM004 (ATR 200-1) (C/M static)	AFRM009 (suborbital qualification)	
Impact g	Booster separation only	No requirements	No requirements	No requirements	No requirements	LEM docking only

Table 12-8. Command Module Inner Structure Tests by Mission Phase (Cont)

Mission Phase Environment Condition	Lunar Orbit	Transearth Coast	Reentry	Earth Landing		Design Verification	Analysis Verification
				Land	Water		
Thermal	AFRM 008 (ATR 611) (cold soak)	AFRM 008 (ATR 611) (cold soak)	AFRM 005 (ATR 200-2) (static thermal) AFRM 009 (suborbital) ATR 209-1, -2 (aft heat shield static) ATR 212-2 (window tests)				
Aerodynamic pressure	No requirement	No requirement	AFRM 009 (suborbital qualification) ATR 209-3-2 (aft heat shield static) AFRM 004 (ATR 200-1) (C/M static) ATR 212-2 (window test)	No requirement	No requirement	ATR 219 (heat shield stringer) B-19 (parachute development)	ATR 214-2B (instability of sandwich cylinders) ATR 214-2E (instability of sandwich cones)
Vibration	AFRM 006 (acoustic, vibration — ATR 601, 602, 603)	AFRM 006 (acoustic, vibration — ATR 601, 602, 603)	AFRM 009 (suborbital) AFRM 006 (acoustic, vibration — ATR 601, 602, 603)	No requirement	No requirement	ATR 205 (vibration & acoustic, typical panel) ATR 206 (sonic vibration, typical panel) ATR 210-5.6 7; 210-9.3 (vibration)	
Inertia g			AFRM 004 (ATR 200-1) (C/M static) ATR 209-1, -2 (aft heat shield static)				ATR 309-2 (joints)
Impact g	LEM docking only	No requirement	No requirement	AFRM 005 (ATR 201-1) (drop test)	AFRM 007 (ATR 201-1) (drop test)	B-28, -1, -2 (impact) ATR 213 (meteoroid impact) ATR 210-9.1 (ultimate g loads) ATR 210-9.2 (ultimate g loads)	ATR 309-2 (joints)

Table 12-9. Service Module Tests by Mission Phase

Mission Phase Environment Condition	Launch	Maximum QBoost	End Boost	Earth Orbit
Thermal	B-12 (transonic abort) B-13, B-15 (launch environment) AFRM 002 (maximum q abort) AFRM 009 (suborbital qualification)	B-13 & -15 (launch environment) AFRM 002 (maximum q abort) AFRM 009 (suborbital qualification)	AFRM 012 (7-day earth orbit) AFRM 020 (SPS proof test) AFRM 022 (Saturn V launch environment)	AFRM 008 (ATR 611) (cold soak) AFRM 009 (suborbital qualification) AFRM 001 (propulsion test)
Aerodynamic pressure	B-12 (transonic abort) B-13, B-15 (launch environment) AFRM 002 (maximum q abort) AFRM 009 (suborbital qualification)	B-13 & -15 (launch environment) AFRM 002 (maximum q abort) AFRM 009 (suborbital qualification) AFRM 004 (ATR 600, combined module, & ATR 300, SPS stiffness) ATR 301-1 (outer shell panel test) ATR 301-5 (radial beam test)	AFRM 004 (ATR 600 & 300 static test) AFRM 012 (7-day earth orbit) AFRM 020 (SPS proof test) ATR 301-5 (radial beam test) ATR 302-1 (SPS pressure vessels) ATR 022 (Saturn V launch environment)	AFRM 009 (suborbital qualification)
Vibration	B-12, -13, -15 AFRM 002, 006, 009 ATR 601 (S/C vibration proof) (006) ATR 602 (S/C transmissibility proof (006) ATR 603 (S/C acoustic proof) (006) AFRM 007 (modal)	AFRM 002, 009 AFRM 006 (acoustic & vibration-ATR 601, 602, 603) AFRM 007 (modal)	AFRM 006 (acoustic & vibration-ATR 601, 602, 603) AFRM 007 (modal)	AFRM 009 (suborbital qualification) AFRM 006 (acoustic & vibration-ATR 601, 602, 603) AFRM 007 (modal) AFRM 001 (propulsion test)
Inertia g	AFRM 004 (ATR 600) (command module test) AFRM 002 (maximum q abort) AFRM 009 (suborbital qualification)	AFRM 002 (maximum q abort) AFRM 004 (ATR 600 & 300) AFRM 009 (suborbital qualification) B-13 & -15 (launch environment) ATR 201-5 (radial beam test)	ATR 302-1 (SPS pressure vessels) AFRM 004 (ATR 600 & 300 static test) ATR 301-3 (simulated aft bulkhead test) ATR 301-5 (radial beam test)	AFRM 009 (suborbital qualification) AFRM 001 (propulsion test)
Impact g	No requirement	No requirement	Booster separation only	No requirement

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Table 12-9. Service Module Tests by Mission Phase (Cont)

Mission Phase Environment Condition	Translunar Coast	Lunar Orbit	Transearth Coast	Design Verification	Analysis Verification
Thermal	AFRM 008 (ATR 611) (cold soak) AFRM 001 (propulsion test)	AFRM 008 (ATR 611) (cold soak) AFRM 001 (propulsion test)	AFRM 008 (ATR 611) (cold soak) AFRM 001 (propulsion test)		
Aerodynamic pressure	No requirement	No requirement	No requirement	ATR 304-1 (aft bulkhead splice tie test) ATR 304 (aft bulkhead component test) ATR 304-2 (aft bulkhead component test) ATR 301-8 (SPS tank door test) ATR 308 (RCS engine & tank support)	ATR 301-7 (shear joint test) ATR 301-9 (circumferential and longitudinal joint test) ATR 301-12 (blind rivet joint) ATR 309-2 (joint tests) ATR 214-2B (instability of sandwich cylinder)
Vibration	AFRM 006 (acoustic & vibration - ATR 601, 602, 603) AFRM 007 (modal) AFRM 001 (propulsion test)	AFRM 006 (acoustic & vibration - ATR 601, 602, 603) AFRM 007 (modal) AFRM 001 (propulsion test)	AFRM 006 (acoustic & vibration - ATR 601, 602, 603) AFRM 007 (modal) AFRM 001 (propulsion test)	ATR 206 (vibration, typical panel)	
Inertia g	AFRM 001 (propulsion test)	AFRM 001 (propulsion test)	AFRM 001 (propulsion test)	ATR 304 (aft bulkhead component) ATR 304-2 (aft bulkhead component) ATR 301-8 (SPS tank door test) ATR 308 (RCS engine & tank support)	
Impact g	LEM docking only	LEM docking only	No requirement		

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Table 12-10. Service Module/LEM Adapter Tests by Mission Phase

Mission Phase Environment Condition	Launch	Maximum q Boost	End Boost	Translunar Injection	Design Verification
Thermal	AFRM 009 (suborbital qualification)	AFRM 009 (suborbital qualification)	AFRM 012 (7-day earth orbit) AFRM 022 (Saturn V launch environment)		ATR 402-1 (structural element thermal test)
Aerodynamic pressure	AFRM 004 (ATR 404, static test)	AFRM 004 (ATR 404, static test)	AFRM 004 (ATR 404, static test) AFRM 012 (7-day earth orbit) AFRM 022 (Saturn V launch environment)	AFRM 004 (ATR 404, static test)	ATR 402-3 (aft frame component test) ATR 402-2 (structural element joint test) ATR 403-2 (lower quarter panel test) ATR 403-1 (access door panel test)
Vibration	AFRM 009 (suborbital qualification) AFRM 006 (acoustic & vibration-ATR 601, 602, 603)	AFRM 009 AFRM 006 (acoustic & vibration-ATR 601, 602, 603)	AFRM 009 AFRM 006 (acoustic & vibration-ATR 601, 602, 603)	AFRM 009 AFRM 006 (acoustic & vibration-ATR 601, 602, 603)	
Inertia g	AFRM 009 (suborbital qualification) AFRM 004 (ATR 404, static test)	AFRM 009 (suborbital qualification) AFRM 004 (ATR 404, static test)	AFRM 004 (ATR 404, static test) AFRM 012 (7-day earth orbit) AFRM 022 (Saturn V launch environment)		
Impact g	No requirement	Booster separation only	AFRM 002 (Saturn V launch environment)		

12.3 S&ID TEST PLAN

12.3.1 Launch Escape System Structural Tests

12.3.1.1 Component Tests

12.3.1.1.1 Launch Escape Tower Attachment Fitting Test (ATR 502-2)

12.3.1.1.1.1 Background Information. A small development test will be performed such that design changes, if required, can be made prior to the full-scale tower test. The test will evaluate the integrity of the tower-skirt joint for critical maximum q abort and pad abort loads under predicted thermal environment conditions.

12.3.1.1.1.2 Test Article. The test specimen will consist of a tower skirt longeron attached to a special subassembly which simulates the launch escape tower leg.

12.3.1.1.1.3 Test Objectives. Test objectives are:

1. To perform design development and evaluation tests of the attachment fitting under conditions of simulated design loads at elevated temperature
2. To determine strength, load deflection, and failure mode characteristics of the fitting assembly
3. To verify analysis methods
4. To obtain sufficient information to make design improvement prior to the full-scale static tests of the tower

12.3.1.1.1.4 Test Conditions. The attachment fitting will be placed in a suitable test fixture such that critical maximum q abort and pad abort loads can be imposed and reacted in manner simulating actual conditions. The specimen will be subjected to a thermal environment of 600 F during the destruction test.

12.3.1.1.1.5 Test Plan. Tests will be performed in the following sequence:

1. Loads will be applied at room temperature in 10-percent increments up to limit load for pad abort conditions.

2. Loads will be applied at room temperature in 10-percent increments up to limit load for maximum q abort

3. Loads will be applied at room temperature in 10-percent increments up to ultimate load for pad abort conditions

4. Loads will be applied at room temperature in 10-percent increments up to ultimate load for maximum q abort conditions

5. The specimen will be heated to 600 F and then loaded to failure using the maximum q abort condition

12.3.1.1.1.6 Facilities and Equipment. This test will be performed at the S&ID Engineering Development Laboratories, Downey, California. Strain and deflection transducers with applicable recording equipment will be required.

12.3.1.2 Subassembly Tests

12.3.1.2.1 Launch Escape Tower Separation Fitting Test (ATR 500-1)

12.3.1.2.1.1 Background Information. The tests performed under ATR 500-1 will evaluate the structural integrity of the redesigned launch escape tower dual-mode explosive separation housing for a critical maximum q tumbling abort condition. This housing will not be available during the no. 1 static test program (ATR 500).

12.3.1.2.1.2 Test Article. The test article will consist of a complete prototype separation housing without thermal insulation or protective covering. A dummy pyrotechnic bolt will be substituted for the spacecraft bolt.

12.3.1.2.1.3 Test Objectives. The test objectives are to evaluate the structural integrity and failure mode characteristics of the housing assembly.

12.3.1.2.1.4 Test Conditions. The separation housing will be placed in a suitable test jig such that axial loads, shear loads, and moments can be applied simultaneously. No thermal environment will be simulated. The test fixture will have the capacity to react the loads in a manner similar to that of the Command Module interface. To compensate for the decreased mechanical properties at design temperature, the test loads will be increased by a factor based on the ratio of the allowables at room temperature and at design temperature.

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12.3.1.2.1.5 Test Plan. The test plan is as follows:

1. The specimen will be installed in the test fixture and the dummy bolt torqued to 200 ± 10 ft-lb. Strain gauges placed on the bolt will measure the amount of preload induced in the bolt due to the applied torque. Following this procedure, an axial tensile load will be applied to determine bolt stress due to pure tension.

2. Limit test loads will be applied in ten equal increments and then dropped to zero to check for permanent set.

3. Ultimate test loads will be applied in ten equal increments and then dropped to zero to check for permanent set.

4. Loads will be applied in 10-percent increments of ultimate load until failure is reached.

12.3.1.2.1.6 Facilities and Equipment. This test will be performed at the S&ID Engineering Development Laboratories, Downey, California. Strain and deflection transducers with applicable recording equipment will be required.

12.3.1.3 Complete Assembly Tests

12.3.1.3.1 <u>Launch Escape Tower Static Structural Tests (ATR 500)</u>

12.3.1.3.1.1 Background Information. The tests performed under ATR 500 will evaluate the structural integrity of the launch escape tower for critical pad abort and maximum q abort loading environments. A launch escape tower and skirt will be utilized in the test program. The test effort will establish confidence in the design before the Little Joe II flight test program.

Stiffness evaluation tests will also be performed under ATR 500. These tests will determine deflections of the launch escape tower for comparative evaluation with deflection analysis.

12.3.1.3.1.2 Test Article. The test article will consist of a complete prototype launch escape tower-and-skirt structural assembly. The structure will not be provided with thermal insulation or protective coating of any kind. The specimen will be provided with GSE fittings and separation housings.

12.3.1.3.1.3 Test Objectives. The test series outlined herein has been formulated to satisfy the following objectives:

1. To evaluate the structural integrity of the launch escape tower-skirt assembly for critical aerodynamic and inertia loading

2. To verify analytical rigidity analysis of the tower-skirt assembly for a shear-and-moment condition

3. To determine the magnitudes of secondary stresses, the load redistribution due to plasticity effects, and the mode of failure of the tower-skirt assembly

12.3.1.3.1.4 Test Conditions. Primary test objectives will be satisfied by subjecting the tower and skirt assembly to conditions of static load that simulate critical abort conditions. Secondary objectives will be satisfied by deriving the load/deflection data. Thermal environment will be simulated by increasing the loads by a factor of the allowables at room temperature and flight temperature.

12.3.1.3.1.5 Test Plan. Tests will be performed in the following sequence:

Stiffness coefficients
Pad abort
Maximum q abort
Destruction

12.3.1.3.1.6 Facilities and Equipment. These tests will be performed at the S&ID Engineering Development Laboratories, Downey, California. Strain and deflection transducers with applicable recording equipment will be required, as will special fixtures for load application at the skirt/launch escape motor housing interface.

12.3.1.3.2 <u>Launch Escape Tower Static Rocket Firing Test (ATR 501)</u>

12.3.1.3.2.1 Background Information. Tests performed under ATR 501 will evaluate the structural reaction to dynamic loads caused by rapid thrust buildup and thrust level variations during the escape motor burning period. The tests will also determine thermal and structural effects of nozzle exhaust plume impingement and will establish a random vibration environment for the launch escape system during aborts. The structural damping characteristics of the escape system will also be determined.

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12.3.1.3.2.2 Test Article. The test article will consist of a complete launch escape system utilizing an inert tower jettison motor. The specimen will not be equipped with thermal covering, electrical systems, or separation housings. The specimen will simulate spacecraft weight and CG location.

12.3.1.3.2.3 Test Objectives. The test objectives are:

1. To verify the structural integrity and design soundness of the prototype launch escape tower and skirt assembly under actual conditions of rocket thrust loads, vibration, and exhaust temperature

2. To determine the vibration levels of the launch escape motor and the vibration transmission characteristics of the launch escape tower

3. To determine heat paths and the suitability for pad abort of the insulation material on the skirt

4. To determine temperatures and induced stresses in selected locations of the launch escape system

5. To evaluate the environmental effects on flight instrumentation.

12.3.1.3.2.4 Test Conditions. The launch escape system will be mounted vertically on a test stand by means of the four tower attach points. A flight restraint system will be employed as a safety precaution in the event of primary structural failure of the specimen.

12.3.1.3.2.5 Test Plan. An initiator impulse will be directed to the launch escape motor and pitch control motor simultaneously.

12.3.1.3.2.6 Facilities and Equipment. The test will be performed at the Potrero facility of the Lockheed Propulsion Company. Test instrumentation will consist of strain gauges, thermocouples, accelerometers, heat flux meters, microphones, and motor chamber pressure transducers. Oscillographs will record all strain and temperature data, and magnetic tape will be used to record vibration and acoustic data.

12.3.2 <u>Command Module Structural Tests</u>

12.3.2.1 Component Tests

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12.3.2.1.1 Static Test of Frames and Miscellaneous Support Structure - Crew Compartment Heat Shield (ATR 209-3)

12.3.2.1.1.1 Background Information. Tests under ATR 209-3 are designed to verify the structural integrity of miscellaneous crew compartment heat shield support structural components. These tests are necessary to define the strength properties of these components under various load conditions and to ensure against a premature failure occurring in this area.

12.3.2.1.1.2 Test Articles. The test articles as defined in ATR 209-3 will consist of:

1. Two 4-inch assemblies of the inner-structure-to-heat-shield attachment ring at $X_c = 42.665$.
2. Three 15-inch assemblies of the inner-structure-to-heat-shield attachment ring at $X_c = 42.665$.
3. Ten 1.5-inch x 2.12-inch assemblies of the inner-structure-to-heat-shield attachment at $X_c = 42.665$ (ring fasteners).
4. One truss frame attachment (inner structure to heat shield, location 14).
5. One web frame attachment (inner structure to heat shield frame, location 5).

12.3.2.1.1.3 Test Objectives. The test objectives are:

1. To perform structural development tests on the heat shield support substructure prior to full-scale static strength tests
2. To verify analysis methods and design feasibility of the affected structural assemblies.
3. To determine load-versus-deflection and strain characteristics of the structure at room temperature

12.3.2.1.1.4 Test Conditions. The following conditions will be tested:

1. Test Condition I - Thermal Contraction

   Condition I tests will determine whether the heat shield attachment assembly at $X_c = 42.665$ will sustain the expected load due to thermal contraction of the heat shield structure.

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2. Test Condition II - Abort Shear Loads (X_c = 42.665 Ring)

   Test objectives will be satisfied by subjecting the heat shield attachment assembly at X_c = 42.665 to direct shear loading.

3. Test Condition III - Abort Shear Loads (Ring Fasteners)

   Condition III tests will determine the strength properties of the fastener assembly at station X_c = 42.665 under direct shear loading, which would be present in the event of an abort.

4. Test Condition IV - Aft Frame Loads

   Condition IV tests will determine the ability of the frame members to withstand maximum aerodynamic loads.

12.3.2.1.1.5 Test Plan. All testing will be accomplished under ambient conditions as follows:

1. Test Condition I - Thermal Contraction

   Specimens representing 4-inch sections of the inner-structure-to-heat-shield attachment ring at X_c = 42.665 will be loaded in compression. Loading will be applied such that a maximum deflection reading of 0.200 inch will be developed. Strain versus load will be recorded in ten equal increments of maximum deflection.

2. Test Condition II - Abort Shear Load (X_c = 42.665 Ring)

   Specimens representing a 15-inch section of the inner-structure-to-heat-shield attachment ring will be loaded in direct shear to the maximum test load.

   Loads will be applied in convenient increments to the maximum test load. Strain measurements will be taken at each load increment.

   Should a failure occur, the load at failure and mode of failure will be recorded.

3. Test Condition III - Abort Shear Load (Ring Fasteners)

   Specimens 1.5 inches x 2.12 inches which incorporate the mechanical fastener of the ring attachment at X_c = 42.665 will be loaded in direct tension to induce a shear load across

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the fastener. Loading will be applied by the hysteresis loop method in convenient increments up to the maximum test load. Relative deflection and permanent set between opposite points on the specimen will be continuously recorded by and electrical extensometer.

4. Test Condition IV - Aft Frame Loads

a. Phase 1. Truss Frame

Maximum aerodynamic loads will be applied to the truss frame. Loading (lb/in.) will be applied in convenient increments and will be uniform over the entire bearing surface. Strain readings will be recorded at each load increment to the maximum test load.

b. Phase 2. Web Frame

Testing will be accomplished as in Phase 1, except that the test specimen will be the shear web frame.

12.3.2.1.1.6 Facilities and Equipment. The facilities and equipment available at SID, Downey, California, will be utilized for this test. Hydraulic load struts will be used to apply test loads. Electronic recording equipment will record and monitor load, strain, and deflection measurements.

12.3.2.1.2 Test of Modular Element of Command Module Lower Equipment Bay (ATR 210-9.1)

12.3.2.1.2.1 Background Information. Under ATR 210-9.1, a structural evaluation of typical lower equipment bay modular compartments will be performed. Testing is necessary to verify design of the individual electronic compartments and to ensure satisfactory structural performance of the attachment clamps and coldplates used between the electrical units.

Since the lower equipment bay is a section made up of structural members and honeycomb panels which support the modular units through the use of attachment clamps, a direct analysis of load paths and load-carrying abilities of the compartmental sections is not easily conducted. Therefore, a test of a typical compartment using design loads will verify present analysis of the individual compartments. Through the use of a test specimen incorporating a spacecraft coldplate and attachment clamps, preliminary data can be obtained which can be used to predict the behavior of these articles under launch and landing (impact) conditions. An additional requirement of this test is to demonstrate the feasibility of removal and replacement

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of the electronic modules after expected launch and design limit loads have been applied. This will demonstrate the operation of the clamp attachments when they are mounted on the support panels and test loads are applied.

12.3.2.1.2.2 Test Article. The test article is a modular element of the lower equipment bay consisting of the following:

1. Structural compartments for the DSIF power amplifier and the C-band transponder, including simulated adjacent coldplate and support sections, and spacecraft attachment clamps

2. Spacecraft coldplate used between the amplifier and transponder

3. Loading plates which simulate the amplifier (upper unit) and transponder (lower unit) electronic packages

12.3.2.1.2.3 Test Objectives. Test objectives are:

1. To determine whether the mounting clamp assemblies will sustain launch loads without a marked influence on their operation

2. To determine whether the individual electronic compartments will sustain design limit loads without yielding the mounting clamp assemblies

3. To determine whether the individual electronic compartments will sustain design ultimate loads without failing the mounting assemblies

12.3.2.1.2.4 Test Conditions. Test objectives will be satisfied by subjecting the lower equipment bay modular element to conditions of static loading which will determine the integrity of the structure when design limit and ultimate loads are applied. Test conditions are as follows:

1. Test Condition I - Mounting Clamp Checkout

   Condition I tests will determine the effect of boost loads upon the mounting clamp assemblies. Anticipated loads of approximately 10 percent of design ultimate will be applied, and the mounting assemblies will be checked for evidence of permanent set. The operation of the clamp attachments will also be investigated at the conclusion of testing to demonstrate the feasibility of removing and replacing the modular electronic units after launch loads have been experienced.

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2. <u>Test Condition II - Design Limit</u>

Since analysis and design are based on limit loads as determined by expected launch and landing conditions, static test of the structure to design limit load is necessary to verify the analytical methods employed in the design of each member. Condition II tests will demonstrate the response of the lower equipment bay modular element to limit loads. Deflection measurements along each axis will be taken at each load increment to determine the element's stiffness characteristics.

3. <u>Test Condition III - Critical Resultant</u>

Maximum loading is experienced by the lower equipment bay upon earth landing. Due to the geometry of the bay and attachments, loading is distributed such that the resultant direction of the load upon landing is approximately 56 degrees below the horizontal. Since a failure of the attachments during landing would send projectiles in the general direction of the crew, tests must be performed to ensure that such a failure will not occur. To satisfy this objective, Condition III tests will determine the effect of landing loads on the mounting clamp assembly. Anticipated loads will be applied along the critical resultant direction, and the structure will be checked for evidence of failure.

4. <u>Test Condition IV - Design Ultimate</u>

Condition IV tests will determine whether the modular compartment will sustain design ultimate loads. Ultimate loads will be applied along each of the three orthogonal axes, and deflection measurements will be taken. Failure of the specimen in any direction will conclude testing.

12.3.2.1.2.5 Test Plan. Tests will be performed in the following sequence:

Condition I - mounting clamp checkout
Condition II - design limit
Condition III - critical resultant
Condition IV - design ultimate

Each test condition will consist of three test phases (except condition III, which has only one phase). The phases of each condition are described below.

Testing will proceed in a manner wherein the successful completion of one condition will provide the authority to proceed with the following tests.

Loads will be applied in increments to the maximum test load. The loads will be relieved after the maximum loads are obtained or if a failure occurs.

Instrumentation data will be recorded at each stabilized load increment. Visual observations will be noted where applicable.

1. Test Condition I - Mounting Clamp Checkout

   a. Phase 1

      The simulated amplifier and transponder units will be loaded in the -X direction to approximately 10 percent of design ultimate load. Deflection measurements will be taken at each load interval. The load will be relieved to zero after the maximum test load has been applied. Upon removal of the simulated units, coldplates, clamps, and interface material will be examined for damage or distortion. The observations will be recorded and the units reinstalled.

   b. Phase 2

      The Phase 1 test will be repeated, except that loading will be applied along the +Y axis.

   c. Phase 3

      The Phase 1 test will be repeated, except that loading will be applied along the -Z axis.

2. Test Condition II - Design Limit Load

   a. Phase 1

      The simulated amplifier and transponder units will be loaded along the -X direction in convenient increments to design limit load. Deflection measurements will be taken at each load increment. After limit load is attained, the loading will be relieved to zero and the units removed. The assembly will be examined in the same manner as for Condition I.

12.3.2.1.3 Support Bracket Tests of the Command Module Helium, Fuel, Potable Water, and Combined Potable-Waste Water Tanks

12.3.2.1.3.1 Background Information. Tests will be performed under the following requirements:

ATR 210-5 (helium tank)
ATR 210-6 (potable water tank)
ATR 210-7 (fuel tanks (two))
ATR 225 (combined potable-waste water tanks)

These tests will provide verification of the structural integrity and analysis methods for the tank suspension systems for static and dynamic loads.

12.3.2.1.3.2 Test Article. Support bracketry will be assembled with related command module propellant system tanks on backup structure which simulates the local boundary conditions. The tanks will be similar to those used on the spacecraft, but will be unqualified and as follows:

Helium tank (ME 192-0007-0003)
Potable water tank (ME 192-0007-0003)
Fuel tanks (ME 282-0007-0002)
Combined potable-waste water tank (ME 192-0014)

12.3.2.1.3.3 Test Objectives. These requirements will be arranged in two phases of testing: static load tests and dynamic load tests.

1. Phase I - Static Test

   Static tests of the tank and bracketry mounted on the inner structure were designed to meet the following objectives:

   a. To demonstrate that the tank bracketry and interfacing tank mounting flange can sustain limit design loads without yielding, and ultimate design loads without failure

b. Phase 2

The Phase 1 test will be repeated, except that loading will be applied along the +Y axis.

c. Phase 3

The Phase 1 test will be repeated, except that loading will be applied along the -Z axis.

3. Test Condition III - Critical Resultant

Test Condition III has only one phase. The simulated units will be loaded simultaneously in the -X and -Z directions to the design ultimate load. Loading will be applied in convenient increments, and deflection measurements will be taken at each interval.

4. Test Condition IV - Design Ultimate

a. Phase 1

The simulated units will be loaded in the -Z direction to design ultimate load. Convenient load increments will be used, and deflection measurements taken at each increment.

b. Phase 2

The Phase 1 test will be repeated, except that loading will be applied along the -X axis.

c. Phase 3

The Phase 1 test will be repeated, except that loading will be applied along the +Y axis.

12.3.2.1.2.6 Facilities and Equipment. The facilities and equipment available at S&ID, Downey, California, will be utilized for this test. Hydraulic load cells, electronic deflection indicators, and associated equipment will be used.

b. To determine the strains and deflections at selected locations under the simulated critical design conditions

c. To determine the failure mode by a destruction test

2. Phase II - Dynamic Tests

a. To determine the structural response under sinusoidal excitation (mechanical vibration)

b. To determine the structural integrity under random vibration

12.3.2.1.3.4 Test Conditions. The test phases are listed in the sequence of testing.

1. Phase I

The test objectives will be met for the static load tests by subjecting the bracket and tank assembly to inertial loads for critical combinations of a triaxial loading system.

2. Phase II

The test objectives will be met for the dynamic load tests by subjecting the specimen to low- and high-level excitation in various frequency ranges of interest to determine significant resonant frequencies, transmissibilities, and mode shapes. Dwells will be conducted at predominant response frequencies to confirm modes. These data will be determined in each of three axes of a predetermined orthogonal system. The specimen will be instrumented to determine modes and secondary structural response.

12.3.2.1.3.5 Test Plan. Tests will be performed in the sequence presented under Test Conditions. Suitable test fixtures and equipment both for supporting the specimen and for applying the loads will be used as required for each test phase.

Strain gauges, deflection devices, and accelerometers will be installed on the specimen as required for each test phase. Measurements will be taken and recorded at each stabilized increment for the static tests, and continuously for all dynamic tests. The performance of the specimen structure under test will be controlled by monitoring the appropriate instrumentation.

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1. Phase I - Static Load Tests

For each inertial load condition, test fixtures and equipment will apply loading to the tank. The specimen sidewall structure will be mounted on fixtures to react the applied loads on the individual or combined tanks.

The same loading procedure will be followed for each of the test conditions, and satisfactorily completed to limit load before changeover to Phase II tests. After completion of Phase II tests, loading will resume for Phase I to ultimate and failure.

Loads will be applied in approximately ten equal increments to design limit (ultimate/1.5). Loads will be relieved in the same increments to zero, and the specimen will be checked for permanent set. For the design ultimate test, loads will be applied in 15 equal increments. Selected strain and deflection data will be recorded and monitored for test control.

2. Phase II - Dynamic Load Tests

The specimen will be subjected to sinusoidal excitation spectra in each of the three orthogonal axes, first at low exploratory levels and then at final qualifying levels, to determine significant resonant frequencies, transmissibilities, and mode shapes.

Sufficient orthogonal measurements will be taken to adequately describe these characteristics. Where applicable, key functional parameters will be monitored during this resonance search.

The test records will contain alternating stress (psi) versus frequency (cps) data on a semi-log scale for all tests as an X-Y type plot from the strain gages.

Sinusoidal data will be presented as an X-Y plot of peak acceleration (± g) versus frequency (cps) using log-log scales. If significant waveform distortion occurs, a sample of the distorted waveform will be recorded. Both the acceleration amplitude (g) and time (millisecond) scales will be clearly marked on the record.

After the sinusoidal characteristics have been determined, the specimen will be subjected to the appropriate random vibration spectrum separately in each of three orthogonal axes. The maximum levels will not exceed a specified time span.

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Random vibration data will be reduced using a waveform analyzer. The data will be presented as mean square acceleration density (g^{-2}/cps) versus frequency (cps) using log-log scales.

12.3.2.1.3.6 Facilities and Equipment. These tests will be performed at the S&ID Engineering Development Laboratories, Downey, California. Special fixtures will be required for the support of the specimen for the Phase I and Phase II tests. Strain, deflection, load, and pressure transducers and related recording equipment will be necessary for data acquisition. Hydraulic load struts and pressure-regulating units, and a fixture for load and pressure application and reaction will be required for load application. For the dynamic load test, a 30,000-pound force (sinevector) electrodynamic dynamic test system, including an electronic amplifier, a sine control console, and an automatic random equalizer/analyzer, will be required.

12.3.2.1.4 <u>Typical Attachment Test of Launch Escape Tower and Forward Heat Shield to Inner Structure (ATR 211-4)</u>

12.3.2.1.4.1 Background Information. Tests under ATR 211-4 are designed to verify the structural integrity of a typical attachment of the LES tower and forward heat shield to the inner structure. These tests are necessary to define the strength properties of the various items in the component to ensure that a premature failure does not occur in this area.

12.3.2.1.4.2 Test Article. The test article will be comprised of a simulated section of the heat shield attachment joint fabricated and assembled in accordance with heat shield design drawing V16-932625.

12.3.2.1.4.3 Test Objectives. The test objectives are:

1. To determine bolt torque requirements and obtain specified axial bolt preloads

2. To determine the effect of axial preload on bolt during load application to joint members

3. To demonstrate that the joint can sustain limit design load without yielding, and ultimate load without failure

4. To determine load-versus-deflection and strain characteristics of the structure at room temperature

5. To determine the maximum load capability and mode of failure for a selected test condition

12.3.2.1.4.4 Test Conditions. Test objectives will be met by subjecting the specimen to various conditions of static loading in the following sequence:

1. <u>Test Condition I - Bolt Torque Versus Axial Load</u>

   The Condition I test will determine the bolt torque requirements to obtain specified axial preloads.

2. <u>Test Condition II - Maximum Shear Due to Tower Leg</u>

   The Condition II test will demonstrate that the joint can sustain shear and axial tension loads up to limit load without yielding, and ultimate load without failure.

3. <u>Test Condition III - Maximum Compressive Tower Load</u>

   The Condition III test will demonstrate that the joint can sustain shear and axial compression loads up to limit load without yielding, and ultimate load without failure.

4. <u>Test Condition IV - Maximum Shear and Moment Loads Due to Heat Shield</u>

   The Condition IV test will demonstrate that the joint can sustain shear and moment loads up to limit load without yielding, and ultimate load without failure.

5. <u>Test Condition V - Combined Heat Shield and Tower Leg Loads</u>

   The Condition V test will demonstrate that the joint can sustain shear, axial tension, and moment loads up to limit load without yielding, and ultimate load without failure.

12.3.2.1.4.5 Test Plan. Tests will be performed in the sequence indicated in Test Conditions.

The test article will be placed in a suitable fixture for application and reaction of loads. Each test condition will be completed before proceeding to the subsequent conditions. All tests will be performed at room temperature. Approved torque wrenches and other load application equipment will have the capability of applying the loads in increments. Instrumentation data will be recorded at each stabilized load increment.

1. <u>Condition I (Preload Torque Requirements)</u>

   The tower leg tiedown bolt will be torqued in convenient increments until a specified axial preload in the bolt is realized for five independent cycles. The load will be recorded versus the torque required.

   For Conditions II through V, the tower leg tiedown bolt will be torqued to a preload value to be determined from Condition I, and component loads will be applied for the particular condition.

2. <u>Condition II (Maximum Shear Due to Tower Leg)</u>

   Ultimate shear and axial tension loads will be applied in convenient increments.

3. <u>Condition III (Maximum Compressive Tower Load)</u>

   Tower leg loads and heat shield casting loads will be applied concurrently in convenient increments.

4. <u>Condition IV (Maximum Shear and Moment Loads Due to Heat Shield)</u>

   Shear and moment loads will be applied through the heat shield in convenient increments until the specified load is reached.

5. <u>Condition V (Combined Heat Shield and Tower Leg Loads)</u>

   Tower leg loads of shear and axial tension will be applied concurrently with heat shield casting loads of shear and moment in convenient increments until ultimate load is reached.

12.3.2.1.4.6 Facilities and Equipment. The facilities and equipment at S&ID, Downey, California, will be utilized for this test. Hydraulic load cells, deflection gauges, and strain gauges will be used in conjunction with electronic recording equipment to make the necessary measurements.

12.3.2.1.5 <u>Structural Test of Crew Compartment-Heat Shield Stringer Assembly (ATR 219)</u>

12.3.2.1.5.1 Background Information. Under ATR 219, tests for verification of structural analysis methods for the crew compartment-heat shield stringer assembly will be performed.

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12.3.2.1.5.2 Test Article. The command module structural components as defined in ATR 219 will consist of:

6-inch x 6-inch heat shield section less ablator
6-inch x 6-inch inner structure section
6-inch stringer and channels

The parts will be of spacecraft configuration.

12.3.2.1.5.3 Test Objectives. Four test conditions are required to fulfill the following objectives:

1. Determine spring rate and mode of failure for stringer assembly under a racking load

2. Determine the allowable tensile loadings of a stringer assembly

12.3.2.1.5.4 Test Conditions. The following conditions will be tested:

Condition I - spring rate (stringer fully compressed)
Condition II - spring Rate (stringer half-extended)
Condition III - spring rate (stringer fully extended)
Condition IV - tensile test

For Conditions I, II, and III, the test objectives will be met by subjecting the stringer assembly to a racking load. For Condition IV, the test objectives will be met by subjecting the stringer assembly to a tensile load.

12.3.2.1.5.5 Test Plan. The test plan is as follows:

1. Condition I

   The inner structure honeycomb panel will be held in a fixed position. Before applying load, the specimen-to-fixture geometry will be measured. A transverse load of 25 pounds will be applied. Upon reaching 25 pounds, the loading direction will be reversed with load applied slowly until the specimen fails. The heat shield and inner structure honeycomb panels must remain parallel and maintain a constant spacing of 1.10 inches through the test. Load-versus-deflection data will be recorded from initial zero load until failure. The mode of failure will be noted.

2. Condition II

   Same as Condition I, except that a spacing of 1.30 inches is required

3. Condition III

   Same as Condition I, except that a spacing of 1.50 inches is required

4. Condition IV

   The inner structure honeycomb panel will be held in a fixed position. A tensile load will be applied until failure occurs. The load at yield and ultimate failure will be recorded. The mode of failure will be noted.

12.3.2.1.5.6 Facilities and Equipment. These tests will be performed at the S&ID Engineering Development Laboratories, Downey, California. Deflection and load recording equipment are required. Hydraulic load struts and pressure regulating units, and jigwork for load application and reaction will also be necessary.

12.3.2.1.6 Test of Command Module Crew Hatch — Heat Shield Tongue-and-Groove Edge Members (ATR 224)

12.3.2.1.6.1 Background Information. Under ATR 224, test specimens representative of heat shield tongue-and-groove edge members will be subjected to test conditions which will determine the following:

1. The quality of the friction material applied to the tongue and groove members

2. The tensile and compressive strengths of the tongue-and-groove members

Information on these parameters is necessary because the tongue-and-groove edge is used not only in the hatch area but also in many heat shield splice areas.

12.3.2.1.6.2 Test Article. The test specimen will comprise the following:

1. Six 4-inch wide tongue-and-groove edge members with Lubeco CL 5400-2 friction material coated on the mating surfaces. Edge members are to be made from 17-4PH steel (RH 1150) (Condition I specimen).

2. Six 4-inch wide tongue-and-groove edge members as in 1, except that the friction material will be Lubeco CL 5400-4 (Condition I specimen)

3. Six 4-inch wide tongue-and-groove edge members as in 1, except that no friction material will be used on the mating surfaces (Condition II specimens)

4. Six 4-inch wide tongue-and-groove edge members with either Lubeco CL 5400-2 or CL 5400-4 friction material on the mating surfaces (choice to be based on initial testing of the specimens in 1 and 2 above) (Condition III specimens)

12.3.2.1.6.3 Test Objectives. Test objectives are:

1. To determine the mode of failure of the tongue-and-groove edge members

2. To determine the design limit and ultimate loads of the tongue-and-groove edge members when subjected to various environmental conditions

3. To determine the quality of the proposed friction materials to be applied to the tongue-and-groove edge member mating surfaces.

12.3.2.1.6.4 Test Conditions. Test objectives will be satisfied by subjecting the specimens to various environmental conditions which will determine the characteristics of the tongue-and-groove members at room temperature and under simulated reentry heating conditions.

1. <u>Condition I (Friction Material Evaluation)</u>

   Condition I tests will determine the ability of the two friction materials to withstand slipping loads induced by direct tensile loading applied to the tongue-and-groove edge members. Tensile tests will be performed at room temperature and elevated temperature (600 F) to determine the comparative properties of both materials in ambient and simulated reentry environments. The assembly will not be restrained from becoming unlocked, and testing will stop if a failure occurs or if the members become disengaged.

2. <u>Condition II (Compression Test)</u>

   Condition II tests will determine the bare compressive strength of the edge members. Compression tests will be conducted at room temperature and at 600 F to determine the limit and ultimate strengths of the assembly under these conditions. The mode of failure in compression will also be recorded.

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3. Condition III (Tensile Test)

Tests conducted under Condition III will determine the tensile strength properties of the tongue-and-groove assembly. The friction material yielding the best results in Condition I tests will be used on the mating surfaces of Condition III specimens. A latch assembly will be used to lock the specimens into position to ensure that disengagement does not occur before ultimate loads are applied. Testing will be accomplished at room temperature and at 600 F.

12.3.2.1.6.5 Test Plan. Tests will be performed in the following sequence:

Condition I (friction material evaluation)
Condition II (compression tests)
Condition III (tensile tests)

The test specimens will be mounted in a test fixture that provides for application of test loads as shown in Figure 1. Strain and deflection measurements will be recorded at each increment of load for room temperature tests only. The load at failure will be recorded for all test conditions.

1. Condition I (Friction Material Evaluation)

a. Phase 1

The test specimen will be mounted in the test fixture, and the latch mechanism will not be locked. Tensile loading will be applied in 20-pound increments until the specimen fails or the joint disengages. Testing will be conducted under ambient conditions.

b. Phase 2

Testing will be the same as in Phase 1, except that the temperature environment will be 600 F.

2. Condition II (Compression Tests)

a. Phase 1

The test specimens will be mounted in the test fixture, and the latch mechanism will not be locked. The joint mating surfaces will be checked to ensure that they are dry. A compressive load will be applied in 20-pound increments until the specimen fails or

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disengagement occurs. Testing will be accomplished under ambient conditions.

b. Phase 2

Testing will be the same as in Phase 1, except that the temperature environment will be 600 F.

3. Condition III (Tensile Tests)

a. Phase 1

Testing will be accomplished as in Condition I, Phase 1, except that the latching mechanism will be locked.

Phase 2

Testing will be accomplished as in Condition II, Phase 1, except that the latching mechanism will be locked.

12.3.2.1.6.6 Facilities and Equipment. The facilities and equipment at S&ID, Downey, California, will be utilized for these tests. Environmental chambers and testing machines incorporating deflection and strain indicators will be used.

12.3.2.1.7 Command Module/Service Module Compression Shear Tie Test (ATR 226)

12.3.2.1.7.1 Background Information. Under ATR 226 verification of structural analysis methods for the compression-shear tie will be made. This information is necessary to ensure that the structural integrity of the tie between the command and service module is sufficient.

12.3.2.1.7.2 Test Article. The test article will comprise a complete assembly of the compression-shear tie and interface material, that is, material in the general area of the tie that is relevant to the proper testing of the member.

12.3.2.1.7.3 Test Objectives. Test objectives are as follows:

1. To demonstrate by static test that the area of the command-service module compression-shear tie can sustain ultimate design loads without failure

2. To determine mode of failure of the compression-shear tie by a destruction test

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3. To verify analytical loads analysis of the compression-shear tie member

12.3.2.1.7.4 Test Conditions. Test objectives will be met by subjecting the specimens to various conditions which will determine the desired mechanical properties.

1. Test Condition I (Limit Loads)

   Condition I tests will determine the reaction of the compression-shear tie to design limit loads.

2. Test Condition II (Ultimate Loads)

   Condition II tests will demonstrate the ability of the compression shear tie to withstand design ultimate loads.

3. Test Condition III (Ultimate Load, Reversed Shear)

   Condition III tests will determine the reaction of the compression-shear tie to a shear load of equal magnitude but opposite in direction from Condition II shear loads. Compression loads will be the same as in Condition II.

12.3.2.1.7.5 Test Plan. The sequence will be as follows:

Condition I (Limit Loads)
Condition II (Ultimate Loads)
Condition III (Ultimate Load, Reversed Shear)

Strain gage readings will be taken at each load increment to failure.

1. Condition I (Limit Load)

   Limit loads will be applied in 10 equal increments.

2. Condition II (Ultimate Load)

   Ultimate loads will be applied in 15 equal increments.

3. Condition III (Ultimate Load, Reversed Shear)

   Ultimate loads will be applied as in Condition II above except that shear loads shall be reversed in direction when compared to Condition II shear loading.

12.3.2.1.7.6 Facilities and Equipment. The facilities and equipment at S&ID, Downey, California will be utilized for this test. Hydraulic load cells and strain gages will be used in conjunction with electronic recording equipment to make the necessary measurements.

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12.3.2.1.8 Heat Shield Component Tests, Subcontractor

12.3.2.1.8.1 Background Information. The subcontractor is in general responsible for testing ablative panels to support thermostructural design and to provide analytical verification.

The heat shield component tests are listed under categories of:

1. Thermal, optical, and ablation properties and performance
2. Material and mechanical properties
3. Structural and thermostructural performance

The test results will supply the behavioral parameters required for the design, analysis, and prequalification of the ablative material panels for use on the full scale Apollo heat shield tests.

12.3.2.1.8.2 Test Plans

12.3.2.1.8.2.1 Thermal Performance Test. The thermal properties, thermal conductivity (k), Btu/ft^2/hr., degrees F, specific heat, thermal expansion and contraction, etc., of the materials utilized in the Apollo vehicle heat shield design will be measured in the laboratory. The data from these tests will be utilized in a computer program to arrive at a thermal protective system design, which will ensure that the ablative back face temperature does not exceed a 600 F design requirement during the most critical reentry design conditions.

12.3.2.1.8.2.2 Thermostructural Performance. Avco Corporation will subject bi-material composite beams and panels to various heating, cooling, loading, thermal cycling, and dynamic conditions to ascertain that the proposed C/M heat shield can survive the Apollo flight environments (as simulated by ground tests to determine types of failures) and to correlate analytical predictions with experimental results. The test program is as follows.

12.3.2.1.8.2.2.1 Evaluation of Cold Soak. Bi-material sandwich panel specimens are to be subjected to simulated deep-space environment (programmed coldsoak to -260 F).

The test objective is to evaluate the bi-material thermal structural performance and stress characteristics of the ablator and the steel substructure under Apollo mission conditions.

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12.3.2.1.8.2.2.2 Flat Panel Reentry. Bi-material sandwich panel specimens are to be subjected to a programmed heating of the critical Apollo reentry heating trajectory. The test objective is to evaluate the bi-material thermal structural performance of the ablator, fiberglass edge members, seals, and honeycomb joints, and to ensure that the backface temperature at the ablator does not exceed the 600 F design requirement.

12.3.2.1.8.2.2.3 Temperature Gradient. Ablative panel specimens are to be subjected to a programmed reentry thermal gradient through the thickness of the ablator.

The test objective is to evaluate the degree of conservatism between the measured temperature and the empirical predicted thermal gradients in the ablator.

12.3.2.1.8.2.2.4 Beam Test. Bi-material sandwich beams are to be subjected to bending tests under a thermal programmed cold soak (-260 F) and also a thermal programmed critical reentry heat condition.

The test objective is to evaluate and establish the structural strain compatibility between the ablator and the steel substructure under environmental loading conditions. The beam tests are also being used to determine the loading that will cause catastrophic failure (delamination of the ablator from the substructure). As a preface to the above beam tests, specimens will be utilized to evaluate the bi-material zero stress state of the fabricated composite structure.

12.3.2.1.8.2.2.5 Ablator Stress Concentration. Panel specimens with prescribed stress concentration (through holes in the composite unit) will be subjected to pure tensile conditions at room temperature and at -260 F thermal conditions. The test objective is to determine the detrimental effect of having stress concentrations in the composite heat shield sandwich structural unit, simulating fastener provisions.

12.3.2.1.8.2.2.6 Curved Panel (Cold Soak and Reentry). Curved composite panels mounted in a special parallelogram holding fixture are subjected first to a programmed -260 F cold soak condition and followed by a programmed reentry heating condition. The failure has been designed so that the warpage moments are counter reacted by the fixture which will simulate actual spacecraft conditions. The test objectives are to evaluate the bi-material thermal structural performance of the composite panel, honeycomb edge member, the substructure-to-ablator adhesive bond, the ablative matrix, and the substructure under critical Apollo thermal mission environments.

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12.3.2.1.8.2.2.7 Curved Panel Cyclic Test. Curved composite panels mounted in a special parallelogram test fixture are subjected to sequential thermal conditions of full flight exposure, ascent heating, cyclic cold and hot soak (random drift space orientation), and reentry heating. The test objectives are to evaluate the bi-material thermal structural performance of the composite curved panel, when subjected to the thermal cyclic environment of the spacecraft mission. This test will be used to qualify the bi-material panel against failure of the ablator by delamination from the substructure, and failure of the ablative system to provide a thermal protection to the substructure (limit of +600 F from an actual ±250 F temperature).

12.3.2.1.8.2.3 Special Design Problem Areas. Typical bi-material panels of the crew hatch, abort tower wells, shear compression pads, electrical umbilical, and antenna window, will be subjected to sequential thermal conditions of ascent heating, cold soak, and reentry heating. The basic objective of these tests will be to ensure that the special design areas will satisfactorily perform their individual design functions.

12.3.2.1.8.2.3.1 Crew Hatch Panel. The objective of the crew hatch tests is to demonstrate the operational capability after thermal exposures of ascent heating, during exposures to equilibrium temperatures between -260 F and +250 F, and after critical reentry temperatures.

12.3.2.1.8.2.3.2 Abort Tower Wells. The objective of the abort tower well tests will be to evaluate the ablator-bond performance when subjected to space flight sequential thermal conditions of -260 F followed by reentry heating, and +250 F followed by reentry heating.

12.3.2.1.8.2.3.3 Shear Compression Pad. Mockup specimens of the shear-compression pad structure together with its reacted substructure will be subjected to the critical state design loading at room temperature. The specimen will be loaded to maximum loads and beyond to determine margin of safety. Separate specimens will be employed to investigate perturbation and thermal aspects of the pad area during reentry heating. The objective of the shear-compression pad tests will be the verification of structural adequacy under static and thermally induced load environments.

12.3.2.1.8.2.3.4 Electrical Umbilical. Mock-up specimens of the typical electrical umbilical structural panel installation shall be subjected to reentry heating tests. The objective of the tests is verification of design at the NAA/AVCO interface (umbilical panel periphery).

12.3.2.1.8.2.3.5 Antenna Window. Mockup specimens of the typical antenna window panel structural installation shall be subjected to sequential thermal conditions of ascent, heating, cold soak at -260 F, and reentry heating. The objective of the tests is confirmation of the design adequacy around the NAA/AVCO interface (fused silica window).

12.3.2.1.8.2.4 Dynamic Tests. Bi-material test panel specimens (made of representative substructure and ablator) will be subjected to two series of acoustic and mechanical vibration environments. The vibration environment tests will be conducted during ascent heating, cold soak, and reentry heating. Acceleration and shock tests will also be conducted on the vibration specimens after reentry tests. The acoustic tests will be conducted at simulated environments applicable to the acoustic requirements. The objective of the tests is verification of structural adequacy for the vibration environment requirements through ascent, cold soak, and reentry heating for the Apollo mission.

12.3.2.1.8.2.5 Ablative Failure Criteria Test Program. The ablative failure criteria test program is designed to resolve the bi-material structural integrity aspects of the heat shield associated with the cracking of the ablative material in the parallel ribbon direction when subjected to cryogenic environments. The program is designed to resolve the characteristics of the ablative cracks (crack onset on worst-case condition and maximum gap to prevent 600 F backface temperature), effect of cracks on ablator delamination from substructure, and effect of cracks on structural response and stress levels (mode of failure and maximum change in radius of curvature for bending in meridional and circumferential plans), and to establish a margin of safety of the heat shield structure against ablator delamination.

12.3.2.1.8.2.5.1 Beam Bending Specimens. Bi-material composite beams with varying thickness of ablator and ribbon direction will be subjected to test at temperatures from -260 F to +250 F to obtain mode of failure, load at failure, and crack width at zero curvature.

12.3.2.1.8.2.5.2 Tension and Compression Specimens. Bi-material composite specimens with varying thickness of ablator and ribbon direction will be subjected to tensile and edgewise compression at temperatures from -260 F to +250 F to obtain mode of failure and load at failure.

12.3.2.1.8.2.5.3 Vibration. Bi-material composite panels and beams with varying thickness of ablator will be subjected to sinusoidal and random mechanical vibration levels as specified in MC364001C (procurement specification) at temperature from -260 F to +250 F to obtain mode of failure, crack propogation, delamination characteristics, and inertia g levels at failure.

12.3.2.1.8.2.5.4 Toroidal Shell (Aft Heat Shield). The toroidal shell structure which is essentially a thin shell stiffened only in its meridional plane by corrugations cannot be compared structurally to the steel honeycomb

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sandwich behavior, and hence a special test program is required to evaluate the failure criteria.

12.3.2.1.8.2.5.4.1 Meridional Bending. Simulated sections of the bi-material toroidal shell with the maximum thickness of ablator will be subjected to meridional bending at temperature from -260 F to +250 F and reentry heat flux to obtain the mode of failure, load at failure, and crack width at zero change in curvature.

12.3.2.1.8.2.5.4.2 Circumferential Bending. Simulated sections of the bi-material toroidal shell with the maximum thickness of ablator will be subjected to circumferential bending at temperature from -260 F to +250 F and reentry heat flux to obtain mode of failure, load at failure, and absence of crack at zero change in curvature.

12.3.2.1.8.2.5.5 Maintenance Door Panel. Simulated bi-material maintenance door panel specimens (with fastener plugs) shall be mounted in a test fixture to simulate edge conditions. They will be subjected to sequential thermal environment of ascent heating, hot and cold cycling (-260 F to +250 F) and followed by reentry heat flux. The testing time shall encompass a total of 336 hours for total mission simulation. The test objectives are to determine effect of fastener plugs on ablator crack, crack width and onset of cracking, change in radius of curvature, and bi-axial effect.

12.3.2.1.8.2.5.6 Rendezvous Window Special Detail. Simulated bi-material rendezvous window panel (full scale and beam section component), which will reflect the actual design parameters, will be subjected to thermal environments from -260 F to +250 F. The tests will evaluate the interaction between the primary ablator matrix and the molded ablator (around the quartz glass window), evaluate the mode of failure, verify the absence of cracks in the molded ablator, and evaluate the bi-material stress levels developed in the rendezvous window well.

12.3.2.1.8.2.6 Repair Evaluation of Curved Panels. The test program is designed to evaluate the ablator repair techniques on large structural panels to ensure feasibility and design capability of meeting Apollo requirements. The bi-material sandwich test panels will be subjected to environment conditions of cold soak, hot and cold cyclic, and reentry flux, and later subjected to beam testing at room temperature conditions.

12.3.2.1.8.2.7 Ablative Panel Qualification Test Program. The qualification test program consists of exposing final configuration heat shield panels to mission extremes of environment. The qualification requirements of the heat shield ablative panels call for the capability of restricting the back-face temperature to a maximum of 600 F during and following sequential exposure to all mission environments up to the time of earth landing. The test program is designed to demonstrate that the selected ablative design configuration has the inherent operational design capability to withstand the expected environments of preflight, flight, earth orbit and translunar and lunar orbit environments, as well as entry, earth landing, and recovery.

12. 3. 2. 1. 8. 2. 7. 1 Qualification Test Plan. The qualification tests are divided into two phases: (a) mission sequence and (b) off-limit tests.

<u>Phase (a) Mission Sequence</u>. The mission sequence includes transportation and handling (including climatic environments) and sequentially applied maximum environmental design conditions. The tests will be conducted to the maximum specification limits and will be designed to verify the ability of the heat shield panels to withstand Apollo mission design conditions.

<u>Phase (b) Off-Limit Tests</u>. The off-limit tests are to verify critical environmental or functional design margins by testing beyond the specification requirements. The test program which is outlined below will utilize 16 test panels representative of the heat shield main ablator and substructure, and 7 test specimens representative of the critical abort tower well casting (forward heat shield component) complete with proper ablative configuration.

12. 3. 2. 1. 8. 2. 7. 2 Climatic Environment. Panels will be subjected to humidity tests in accordance with MIL-E-5272, followed by salt-fog exposure as specified in MIL-E-4970. These panels will be used for subsequent tests.

12. 3. 2. 1. 8. 2. 7. 3 Vibration Plus Launch Loads (Launch and Boost). Test panels, suitably mounted, will be subjected to simultaneous application of maximum launch and boost loads and random vibration at specified mission normal levels. Six specimens will be tested for a duration of 15 minutes each.

12. 3. 2. 1. 8. 2. 7. 4 Vacuum Plus High Temperature (Translunar with Solar Radiation). Panels used for previous tests will be individually placed in a vacuum chamber capable of maintaining a vacuum of 10^{-6} mm Hg. at room temperature. The panel temperature will be raised to +250 F, placed in the chamber, which will then be evacuated to its maximum capacity. This condition will be held for 160 hours.

12. 3. 2. 1. 8. 2. 7. 5 Vacuum Plus Low Temperature (Translunar Without Solar Radiation). The same panels used in high-temperature tests will be subjected to same vacuum after being lowered in temperature to -260 F. Each test duration will be 160 hours.

12. 3. 2. 1. 8. 2. 7. 6 Vacuum-Temperature Cycling (Translunar Random Drift). The purpose of this test is to determine the heat shield conformance

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to transearth and translunar spacecraft re-orientation. Effects of exposing the cold (-260 F) side of the command module to solar radiation will be measured. The test specimen will be placed in a vacuum chamber (10^{-6} mm Hg.), and the temperature will be reduced to -260 F. The ablative face will then be heated with a flux of 460 Btu/ft^2/hr for three hours, representing solar impingement. The chamber will then be cooled at the maximum rate possible without exceeding design thermal stress, until the ablator-substructure interface temperature is again -260 F. This cycle will be repeated for 336 hours. At the end of cycling, the pressure will be raised as rapidly as possible, but not in excess of Apollo design limits.

12.3.2.1.8.2.7.7 Entry Heating — Loading and Vibration (Reentry). The ablative side of the heat shield panel will be subjected to programmed radiant heating in accordance with SID 62-1231 (trajectory HSA-3). Simultaneous with heating, the panel will be subjected to reentry loads of aerodynamic heating and interaction loads, plus random vibration inputs specified as mission normal in the procurement specification.

12.3.2.1.8.2.7.8 Temperature Gradient Test (Translunar Random Drift). One end quarter of the panel will be enclosed in a chamber, and the temperature will be reduced until any point of the ablative panel backface reaches -260 F. Simultaneously, the opposite end quarter panel will be exposed to 460 Btu/ft^2/hr. When the backface temperature of the radiant-heated quarter panel reaches equilibrium, temperature values will be maintained for 16 hours.

12.3.2.1.8.2.7.9 Vibration and Temperature (Off-Limit Test, Translunar, Transearth, Orbit and Reentry). The temperature on the ablative side of the heat shield panel will be tested from minimum to maximum, with temperature values referenced to the ablative panel backface. The axis of vibration will be oriented in the direction in which the panel is most sensitive. The level of vibration will be increased over mission normal as the temperature increases in accordance with the following schedule:

Vibration Level	Temperature
1	-260 F
2	-100 F
3	+300 F
4	+450 F
5	+600 F

[redacted] [redacted]

12.3.2.1.8.2.7.10 Low-Temperature — Loading (Off-Limits, Translunar, Transearth, Lunar Orbit). The test panel and fixture will be placed in a chamber, and the temperature will be brought to -260 F. At this stabilized temperature, aerodynamic pressure loads and spacecraft component interaction loads representing worst-case mission conditions will be applied. After five minutes of constant loading, the specimen will be returned to unloaded room temperature and inspected for evidence of structural failure. This test cycle will be repeated, increasing the loads 25 percent from initial loading. Recycling will continue with 25 percent of initial load increases each time, until the specimen shows structural failure.

12.3.2.1.8.2.7.11 Entry Heating — Loading (Off-Limits Reentry). Test panels will be subjected to radiant heating in accordance with SID 62-1231 (trajectory HSE-6). Simultaneously, the panel will be loaded with aerodynamic pressures and interaction loads.

12.3.2.2 Subassembly Tests

12.3.2.2.1 Structural Verification of Crew Support System (ATR 104)

12.3.2.2.1.1 Background Information. The tests performed under ATR 104 will evaluate the structural integrity of the crew support system for critical impact loads. This test effort will establish confidence in the design prior to manned flight.

A vibrations test will also be performed on the couch to evaluate vibration transmissibility characteristics of the couch assembly.

12.3.2.2.1.2 Test Article. Two sets of couch assemblies will be utilized in support of this test effort. A basic couch (non-spacecraft) will be available for the vibration test program. This couch will be modified to simulate spacecraft center of gravity and weight.

The structural test will be supported by a spacecraft crew couch equipped with a complete restraint system and shock attenuation system. The test article will be identical to spacecraft flight hardware.

12.3.2.2.1.3 Test Objectives. The test series outlined herein has been formulated to satisfy the following objectives:

1. To demonstrate, by static test, that the crew couch assembly can sustain limit design loads without yielding

2. To demonstrate, by static test, that the crew couch assembly can sustain ultimate design loads without failure

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[redacted]

3. To determine maximum load capabilities and mode of failure in crew couch assembly

4. To determine vibration transmissibility and response of the crew support system

12.3.2.2.1.4 Test Conditions. The crew support system will be placed in a test fixture and subjected to loads simulating critical earth impact conditions. The loads will be imposed by a network of straps to obtain the proper load distribution. The restraint system will be utilized to transmit loads to the couch for attach point verifications.

A sinusoidal vibration will be used to excite the crew support system. The vibration will be applied to the fixture in the X, Y, and Z axis, and at 30-degree, 45-degree, and 60-degree increments in the Y-Z plane. Sinusoidal test frequency range will extend from approximately 1/2 cps to 200 cps at levels sufficient to excite the crew support system.

12.3.2.2.1.5 Test Plan. A basic couch (non-spacecraft) will support the vibration phase of the test program. This couch will be vibrated to various levels of excitation and then delivered to crew systems for crew performance tests.

A spacecraft couch will be available for the structural evaluation tests. The couch will first be subjected to a proof loading condition for two critical earth impact conditions. After proof loading the couch will be subjected to ultimate tests and destruction.

12.3.2.2.1.6 Facilities and Equipment. Two test fixtures will be available to support each phase of the test program. The vibration fixture will have sufficient strength and rigidity to accommodate the proposed excitations. The static test fixture will be self-contained with simulated attenuator attach points.

Strain and deflection transducers, oscillograph recording equipment, accelerometers, and high speed motion picture coverage will be required. Tests will be performed at the Space Science Development Facility of S&ID, Downey, California.

12.3.2.2.2 Static Test of Base Section, Subassembly Inner Structure, and Aft Heat Shield Substructure

12.3.2.2.2.1 Background Information. The tests performed under ATR 209-1 and -2 will provide verification of structural analysis methods for cabin pressurization, mission air loads, and maximum heating during reentry.

The structure is the largest structural component of the C/M and will provide the most representative advance information to support design and analysis concepts.

12.3.2.2.2.2 Test Article. This series of tests include the following subassemblies to be arranged in four test specimen setups.

1. Design assembly—heat shield (less ablator), aft compartment (drawing V16-932710, ATR 209-1).

2. Design assembly—inner structure aft section (drawing V16-931750, ATR 209-2).

3. Combined assembly—heat shield to inner structure. (Drawing V16-932711, including thermo insulation V16-327400. Loose item to be installed by the Engineering Development Laboratory.)

4. After completion of the static tests, the test article will be retained by the Engineering Development Laboratory for design configuration changes and instrument installations for a single water drop test. Modification changes, instrumentation, and drop test requirements shall be coordinated with the heat shield and inner cabin structural analysis groups.

All tests will be performed on the inner cabin and heat shield structure components in the mated configuration. All reference to the specimen from this time on refers to the combined articles as defined in item 3 above.

12.3.2.2.2.3 Test Objectives. The test series outlined herein has been formulated to satisfy the following objectives:

1. To perform structural development tests on the primary structural subassemblies of the inner aft section and the aft section heat shield

2. To verify analysis methods, design feasibility, and structural fabrication techniques of the noted structural assemblies

3. To develop methods of testing which will be employed on the final qualification tests of static test articles

4. To determine load versus deflection and strain characteristics of the structure at room temperature

[redacted]

5. To determine induced stresses and deflections at selected locations caused by elevated temperature

12.3.2.2.2.4 Test Conditions. The test conditions are listed in sequence of testing:

Condition I	(maximum q abort)
Condition IIA	(20-g reentry pressure)
Condition IIB	(load-deflection data)
Condition III	(pressurization)
Condition IV	(maximum heating)

The test objectives will be met for the room temperature load tests by subjecting the specimen to simulated conditions of static load, inertial load, and external and internal pressures which occur during the mission. Each load condition will be completed to ultimate before proceeding to the next condition.

The test objectives will be met for the thermal tests by subjecting the specimen to a simulated entry thermal condition which occurs at the ablator-steel bondline.

1. Condition I (maximum q abort)

   Aerodynamic and inertial load will be simulated on the aft heat shield and reacted at the close-out ring frame on the inner structure. The load distribution and interaction between the heat shield and the inner structure will be evaluated.

2. Condition IIA (20-g reentry pressure)

   Aerodynamic pressure loads will be simulated on the aft heat shield and reacted through the inner structure ring frame close-out. The load distribution and interaction between the heat shield and the inner structure will be evaluated.

3. Condition IIB (load-deflection data)

   Load-deflection data on the aft heat shield calibrated compressive point loads will be applied at various locations on the surface of the aft heat shield. The load-deflection data will be used to determine spring constants for landing impact calculations.

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4. Condition III (Pressurization)

The specimen will be internally pressurized to the design burst condition for structural verification of the specimen. Specimen pressurization values exceed ARM-6 pressurization criteria for current spacecraft design. Because the specimen design was based on higher pressure requirements, these values will be used for the test. Strains and deflections will be monitored and recorded at all increments of pressure.

5. Condition IV (Maximum Heating)

The entire outer surface of the aft heat shield will be heated in a specified manner to a stabilized maximum temperature. The functional characteristics of the heat shield attachments and the induced stresses and deflections in the heat shield will be evaluated.

12.3.2.2.2.5 Test Plan. Tests will be performed in the sequence presented under test conditions for both the thermal and room temperature load phases. For these tests the specimen of the command module will be attached to the same load reacting fixture at the Station X_C 42.6 ring frame. Suitable test fixtures for application of loads, pressures, or thermal simulation will be used or required for each condition. All thermocouples, strain gages, and deflection devices will be installed on the specimen before the test.

Instrumentation will be measured and recorded as a function of time for the thermal tests and at each stabilized increment for the load tests.

The performance of the structure under test will be controlled by monitoring the appropriate instrumentation.

For each condition of the room temperature load tests, test fixtures will apply test loads to the appropriate structure. The inner structure will be mounted on the basic fixture at the forward end. Specimen will be inverted with respect to launch position to reduce the effect of hydraulic gradient during pressurization test.

The same loading procedure will be followed for each test condition and satisfactorily completed before change-over to the next condition.

The specimen will be loaded in convenient increments to the design limit (ultimate divided by 1.5). The load will be relieved in the same increments to zero and check for permanent set will be made. Reload to

[redacted]

the design ultimate will be performed, in selected increments. Test will be terminated if any load increment produces stresses in excess of maximum expected stresses.

Selected strain and deflection data will be recorded and instrumentation will be monitored for test control.

12.3.2.2.2.5.1 Thermal Condition IV. The specimen will be re-oriented in the same basic test fixture to a normal launch position atop the independently supported radiant heat lamp oven to provide better convective heat flow to the specimen.

Thermocouples installed on the bare steel substructure will control the heat output from the quartz lamps through signal feedback to the computer in which the test temperature-time profile is programmed.

Heat will be programmed for a linear temperature rise on the entire outer skin of the bare heat shield substructure to a uniform elevated temperature in each of the heating zones. Shutdown is to occur when either the specified gradient through the sandwich honeycomb heat shield is reached, or the test temperature is stabilized for five minutes. Selected thermal strain and deflection data will be recorded and monitored for test control.

12.3.2.2.2.6 Facilities and Equipment. These tests will be performed at the S&ID Engineering Development Laboratories, Downey, California.

Inaccessible instrumentation will be installed on the heat shield and the cabin structure before final assembly by S&ID Manufacturing.

Special boundary condition and interfacing fixtures will be required for load application and reaction at various locations on the specimen.

Temperature, strain, deflection, load and pressure transducers and related recording equipment are required.

Hydraulic load struts, pressure regulating units, and jigwork for load and pressure application and reaction are required. Radiant heating ovens with quartz lamps and attendant temperature control equipment are also required.

12.3.2.2.3 Test of Typical Section of Command Module Lower Equipment Bay (ATR 210-9.2)

12.3.2.2.3.1 Background Information. ATR 210-9.2 is a design verification test of a typical section of the lower equipment bay. It is the only static test of a large section of the lower equipment bay structure and

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as such will yield the only test information available on the behavior of the lower equipment bay structure and assorted electronic modules in this section when static simulated loads of boost and earth landing are applied. The section will also be tested to verify design limit and ultimate loads.

12.3.2.2.3.2 Test Article. The test specimen is a section of the lower equipment bay consisting of the following:

1. Structural compartments and supporting structure (kick panels) at X_c 19 and X_c 42 for the electronic units listed below:

   PCM unit 1
   PCM unit 2
   Telemetry
   VHF multiplexer
   DSIF power amplifier
   VHF/AM transceiver
   VHF recovery beacon
   C-band transponder
   VHF/FM transmitter
   HF transceiver
   Inverter
   Inverter

2. Spacecraft coldplates to be used between the electronic equipment

3. Loading plates which simulate the electronic units mentioned above

12.3.2.2.3.3 Test Objectives. Test objectives are to determine the following:

1. Whether the action of the attachment clamps is affected by boost loads

2. Whether the lower equipment bay section will sustain design limit loads without yielding the mounting assemblies

3. Whether the lower equipment bay section will sustain design ultimate loads without failing the mounting assemblies.

12.3.2.2.3.4 Test Conditions. In order to satisfy test objectives, conditions of static load will be applied to the lower equipment bay section, and the structure will be checked for any sign of yielding or failure.

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1. Condition I (Boost Loads)

Condition I tests are designed to determine the behavior of the lower equipment bay under statically simulated boost loads. The operation of the mounting clamp assemblies will be checked for malfunction upon completion of each test. Interface material and coldplates will be checked for damage or distortions, and a record of the deflection-load characteristics of the assembly will be taken.

2. Condition II (Design Limit)

Condition II tests will demonstrate the ability of the lower equipment bay to sustain design limit loads without yielding the mounting clamp assemblies. Deflection measurements along each axis will be taken at each load increment to determine the stiffness characteristics of the lower equipment bay section.

3. Condition III (Critical Resultant)

This test condition will verify the integrity of the clamp assemblies and support structure when simulated static loads of earth landing impact are applied along the critical resultant path as determined by analysis. Failure of the mounting assemblies along this line (which as presently calculated is 56 degrees from the horizontal) would send projectiles in the general direction of the crew. Therefore, testing must be accomplished to check the action of the lower equipment bay when subjected to loads in this direction.

4. Condition IV (Design Ultimate)

Static loading of the lower equipment bay to design ultimate loads will determine whether the section will sustain design ultimate load without a failure of the structure.

12.3.2.2.3.5 Test Plan. Tests will be performed in the following sequence:

Condition I (boost loads)
Condition II (design limit)
Condition II (critical resultant)
Condition IV (design ultimate)

Each test condition, except Condition III which has only one phase, will consist of three test phases.

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The test phases of each condition are described separately below. The successful completion of one condition will provide the authority to proceed with the following tests. Loads will be applied in increments to the maximum test load. Loading will be relieved after the maximum loads are obtained or if a failure occurs.

Instrumentation data will be recorded at each stabilized load increment. Visual observations will be noted where applicable.

1. Test Condition I (Boost Load)

   Phase 1. All of the simulated units will be loaded in the -X direction to approximately 10 percent of design ultimate load. Deflection measurements will be taken at each load interval, and the load will be relieved to zero after the maximum test load has been applied. The simulated electronic packages will then be removed. Upon removal of the simulated units, cold-plates, clamps, and interface material will be examined for damage or distortions. The observations will be recorded and the units reinstalled.

   Phase 2. The above test will be repeated except that loading will be applied along the +Y axis.

   Phase 3. The above test will be repeated except that the loading applied in the -Z direction.

2. Test Condition II (Design Limit)

   Phase 1. The simulated units will be loaded along the -X direction in convenient increments to design limit load. Deflection measurements will be taken at each load increment. After limit loads are attained, the loading will be relieved to zero and the structure inspected for evidence of localized yielding.

   Phase 2. The above test will be repeated except that loading will be applied in the +Y direction.

   Phase 3. The above test will be repeated except that loading will be applied in the -Z direction.

3. Test Condition III (Critical Resultant)

   Phase 1. The simulated units will be loaded simultaneously in the -X and -Z direction to the design ultimate load. Loading will

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be applied in convenient increments, and deflection measurements will be taken at the load intervals.

4. Test Condition IV - Design Ultimate

Phase 1. The simulated units will be loaded in the -Z direction to design ultimate load. Convenient load increments will be used, and deflection measurements taken at each load interval.

Phase 2. The above test will be repeated except that loading will be applied in the -X direction.

Phase 3. The above test will be repeated except that loading will be applied in the +Y direction.

12.3.2.2.3.6 Facilities and Equipment. The facilities and equipment available at S&ID, Downey, will be utilized for this test. Hydraulic load cells, electronic deflection indicators, and associated equipment will be used.

12.3.2.2.4 Dynamic Test of Typical Section of Command Module Lower Equipment Bay (ATR 210-9.3)

12.3.2.2.4.1 Background Information. ATR 210-9.3 is a design verification test of a typical section of the lower equipment bay. It is the only dynamic test of a large section of the lower equipment bay structure and will yield the only test information on the dynamic response of the lower equipment bay structure and assorted simulated electronic modules in the section when subjected to dynamic simulated loads of boost and earth landing.

12.3.2.2.4.2 Test Article. The test specimen is a section of the lower equipment bay consisting of the following:

1. Structural compartments and supporting structure (kick panels) at X_c19 and X_c42 for the electronic units listed below:

   PCM unit 1
   PCM unit 2
   Telemetry
   VHF multiplexer
   DSIF power amplifier
   VHF/AM transceiver
   VHF recovery beacon
   C-band transponder

[redacted]IAL

VHF/FM transmitter
HF transceiver
Inverter
Inverter

2. Spacecraft coldplates to be used between the electronic equipment

3. Loading plates which simulate the electronic units mentioned above

12.3.2.2.4.3 Test Objectives. Test objectives are as follows:

1. To evaluate the lower equipment bay structural response in the dynamic environment

2. To evaluate the individual electronic component response when mounted in the lower equipment bay

3. To evaluate coldplate dynamic response when mounted in the lower equipment bay and subjected to a dynamic environment

4. To evaluate the coldplate and electronic module attachment clamps when mounted in the lower equipment bay and subjected to a dynamic environment

5. To determine whether the lower equipment bay will sustain landing impact shock conditions without failure.

12.3.2.2.4.4 Test Conditions. In order to satisfy the test objectives, dynamic conditions of vibration and shock will be applied to lower equipment bay section and the structure will be checked for evidence of damage.

1. <u>Test Condition I (Sinusoidal Vibration)</u>

   Condition I tests are designed to determine the resonant frequencies, transmissibilities, and mode shapes of the basic structure, the various electronic components, and the coldplates.

2. <u>Test Condition II (Random Vibration)</u>

   The tests performed under Condition II will determine the broad-band response of the entire structure and will also evaluate the performance of the coldplate and electronic module attachment clamps.

3. <u>Test Condition III (Shock Loads)</u>

   Condition III tests will determine the ability of the lower equipment bay structure and assorted electronic modules housed in the test section to sustain landing shock loads.

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12.3.2.2.4.5 Test Plan. Tests will be performed in the following sequence:

1. Condition I (sinusoidal vibration)
2. Condition II (random vibration)
3. Condition III (shock loads)

The test phases of each condition are described separately below. The successful completion of one condition will provide the authority to proceed with the following tests.

At the conclusion of each test a visual check of the test article and the clamp assemblies is to be made.

An oscillograph recorder or a camera-oscilloscope will be used to record acceleration amplitude versus time for sinusoidal vibration testing.

Random vibration test data shall be reduced with a wave analyzer such as a TPC analyzer.

Shock testing will be recorded with an oscillograph recorder or a camera-oscilloscope.

1. Condition I (Sinusoidal Excitation)

   A low-level sinusoidal sweep of 5 to 2000 cps will be applied along each of the three orthogonal axes to determine the basic response of the structure, the various electronic components, and the coldplates.

2. Test Condition II (Random Vibration)

   Random vibration will be applied to the entire structure. The attachment clamps and interface material will be examined at the conclusion of Condition II tests to evaluate their performance once broad band vibration loads have been applied.

3. Test Condition III (Shock Loads)

   Landing shock loads will be applied to the entire structure. The equipment will be subjected to the following terminal peak saw-tooth pulse in each of the three orthogonal axes.

Peak	75 g, ±10 percent
Rise time	11 ms, ±1 ms
Decay time	1 ms, ±1 ms

A record including time history and acceleration (g) versus time (ms) of the shock pulse will be taken for each axis of testing. Upon conclusion of tests, the attachment clamps, coldplates, and supporting structure will be examined for evidence of damage or distortions.

12.3.2.2.4.6 Facilities and Equipment. The facilities and equipment available at S&ID, Downey, will be utilized for this test. Vibration test stands and shake tables will be used to apply test vibration loading. Accelerometers and automatic recording equipment will be used to record vibration inputs.

12.3.2.2.5 <u>Test of C/M Inner Cabin and Heat Shield Window Panels and Seals (ATR 212-2)</u>

12.3.2.2.5.1 Background Information. Tests to be performed under ATR 212-2 are designed to verify the structural integrity and sealing characteristics of the C/M window panels. The test conditions were selected to ensure that these areas will be acceptable for full scale verification tests.

12.3.2.2.5.2 Test Article. The test articles as defined in ATR 212-2 will consist of:

1. Inner cabin structure panel assemblies of the hatch (DTT 6502) rendezvous (DTT 6500), and side (DTT 6501) window panel areas

2. Heat shield panel assemblies of the side (V16-932116), hatch (V16-932117), and rendezvous (V16-932118) window areas

3. Glass in sufficient quantities to support the test effort

12.3.2.2.5.3 Test Objectives. Five phases of tests are required to satisfy the following objectives:

Phase I (Inner Cabin Window Pressure Leak Tests)

1. To determine the validity of the window seal configuration

2. To ascertain that the leak rate is within acceptable limits

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Phase II (Inner Cabin Window Panel Strength Tests)

1. To determine by specified air pressure loadings that the glass panels, retainers, and other localized structure can sustain limit design loads without yielding and ultimate loads without failing

2. To determine the deflections for specified pressures at selected locations on the specimen

3. To determine the maximum load capabilities and mode failures for each test condition

Phase III (Heat Shield Window Panel Strength Tests)

1. To define the air load versus deflection and strain characteristics of the heat shield window panels at room temperature.

Phase IV (Heat Shield Window Thermal Tests)

1. To define the thermally induced stresses and deflections at selected locations on the structure

2. To verify the heat transfer and thermal expansion characteristics of the structure

Phase V (Inner Cabin Window Panel Thermal Tests)

1. To define the thermally induced stresses and deflections at selected locations on the structure

2. To verify the heat transfer and thermal expansion characteristics of the structure

12.3.2.2.5.4 Test Conditions. The following conditions for each phase of testing are formulated to meet the test objectives.

Phase I. Specimen will be subjected to pressure, temperature, and time histories.

1. Steady state diffusion rates

2. Qualifying duration time for a specific pressure and temperature environment

Two configurations of the specimen will be provided to determine the redundant capabilities of the seals.

1. Single pane of glass installed in panel structure

2. Double pane of glass installed in panel structure

Phase II. The dual glass window specimen installed in its respective support panel structure will be subjected to pressure levels of the space environment and instrumentation recorded for deflection and permanent set data. Pressurization will be continued to establish a failure mode.

Phase III. The specimen window glass installed in its respective support panel structure will be subjected to a uniform aerodynamic pressure load on its outer surface at room temperature and instrumentation recorded for deflection and permanent set data. Pressurization will be continued to establish a failure mode.

Phase IV. The entire panel and glass will be subjected to simulated critical thermal conditions which occur on the glass and at the ablator-steel bondline.

Phase V. The entire panel and glass will be subjected to simulated critical thermal environmental conditions.

12.3.2.2.5.5 Test Plan. The test phases will be performed in the sequence presented under test conditions.

Phase I, II, and III. Each honeycomb sandwich panel with glass specimens installed will be mounted and sealed in a combined vacuum-pressure and temperature controlled oven. Thermocouples, probes, and deflection devices will be installed as required to monitor and record test data. Diffusion rates will be measured and recorded at stabilized temperature and vacuum. Deflections will be measured and recorded at each stabilized increment for the load tests. The performance of the structure under test will be controlled by monitoring the appropriate instrumentation.

Phases IV and V. Each honeycomb sandwich panel with glass specimens installed will be mounted in a radiant heating oven for proper application of heat. Boundary conditions on the non-ablative coated heat shield will be compensated by the introduction of shielding and insulation.

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12.3.2.2.5.6 Facilities and Equipment. These tests will be performed at the S&ID Engineering Development Laboratories, Downey, California. Special pressure temperature chambers and radiant heating ovens will be required for supporting the specimen panels.

Recording equipment is required to gather data on temperature, leak detection, strain, deflection, pressure, load application, vacuum, and pressure units.

12.3.2.3 Complete Assembly Tests

12.3.2.3.1 <u>Command Module Static Test (ATR 200-1)</u>

12.3.2.3.1.1 Background Information. Under ATR 200-1 full-scale structural evaluation tests will be performed on the Airframe 004 spacecraft command module for critical conditions during abort, orbit, undershoot entry, parachute deployment, and landing phases. These tests support the flights of the non-docking configuration spacecraft and are complemented by thermal tests on the command module under ATR 200-2.

12.3.2.3.1.2 Test Article. A command module of spacecraft configuration will be required and will consist of:

Heat shield less ablator
Inner structure less non-structural systems
Main and drogue parachute fittings, hardware, and sections of harness
Simulated tower with complete attachments for reaction of shear and axial loads and moments.

12.3.2.3.1.3 Test Objectives. Room temperature load tests will be performed on the test article to fulfill the following objectives:

1. To demonstrate by static test that the command module can sustain limit design loads without yielding and ultimate design loads without failure

2. To determine the strains and deflections at selected locations under the simulated critical design loads

3. To determine spring rates and natural frequencies of pilot and drogue chute mortars

12.3.2.3.1.4 Test Conditions. The tests will be performed in the following sequence:

Condition I (aft heat shield — burst)
Condition II (maximum Q abort — tumbling)
Condition III (20,000-foot abort — non-tumbling)
Condition IV (crew couch attachments)
Condition V (main parachute deployment)
Condition VI (drogue parachute deployment)
Condition VII (cabin burst)
Condition VIII (thruster loads on inner structure)
Condition IX (forward heat shield — tower ejection)
Condition X (20-g reentry)
Condition XI (spring rate and frequency of pilot mortar)
Condition XII (spring rate and frequency of drogue mortar)

The test objectives will be met by subjecting the various subassemblies or assembly of the command module to the simulated conditions of static load, inertia load, and external and internal pressures which occur during flight.

1. <u>Condition 1 (aft heat shield burst)</u>

   The exterior of the aft heat shield will be subjected to simulated transient differential pressures which occur during separation of the command module from the service module following initiation of abort after lift-off. The effect of this differential bursting pressure across the aft heat shield will be evaluated.

2. <u>Condition 2 (maximum q abort — tumbling)</u>

   The structural integrity of the command module inner structure will be evaluated under the simulated loading environment of maximum q abort — tumbling condition. The sidewall heat shield will be pressurized, while static test loads are applied to the inner structure to obtain the desired loading distribution.

3. <u>Condition 3 (20,000-foot abort — non-tumbling)</u>

   The structural integrity of the command module forward and sidewall heat shields will be evaluated under the simulated loading environment due to the 20,000-foot abort — non-tumbling condition. The aerodynamic pressure distribution will be simulated on the

[redacted]

heat shield at the same time that static loads are applied through the inner structure. The load distribution and interaction between the heat shield, attachment system, and the inner structure will be verified.

4. Condition 4 (Crew Counch Attachments)

   The attachments to the cabin interior at the forward bulkhead, sidewall, and aft bulkhead ring will be loaded for structural verification of the backup structure under the design conditions.

5. Condition 5 (Main Parachute Deployment)

   The main parachute fitting on the forward bulkhead will be loaded through a section of harness to evaluate the structural capability of the backup structure for various deployment orientations.

6. Condition 6 (Drogue Parachute Deployment)

   The drogue fitting on the access cylinder will be loaded with a section of harness to evaluate the structural capability of the backup structure for various deployment orientations.

7. Condition 7 (Cabin Burst)

   The crew compartment will be internally pressurized to the design burst condition for structural verification.

8. Condition 8 (Thruster Loads on Inner Structure)

   Each of the four simulated thruster tubes on the inner structure will be loaded equally to determine the load distribution and structural integrity of the surrounding forward section.

9. Condition 9 (Forward Heat Shield — LES Ejection)

   Each of the four tower attachments will be loaded equally to evaluate the structural integrity of the heat shield during the ejection condition. The resultant load distribution and deflection characteristics will be evaluated.

10. Condition 10 (20 G Re-Entry)

    The structural integrity of the command module will be evaluated under the simulated 20-g loading environment for undershoot reentry condition. The aerodynamic pressure distribution will be

[redacted]

simulated on the heat shield while static loads are simultaneously applied to the inner structure. The load distribution and interaction between the heat shield, attachment system, and inner structure will be evaluated.

11. Condition 11 (Spring Rate and Frequency of Pilot Mortar)

    Static and vibratory loads will be separately applied to the pilot mortar to determine the spring rate and natural frequency, respectively. The structural integrity of the mortar and backup structure will be evaluated.

12. Condition 12 (Spring Rate and Frequency of Drogue Mortar)

    Same as condition 11.

12.3.2.3.1.5 Test Plan. Tests will be performed in the sequence presented under Test Conditions. The subassemblies or assembly of the command module will be mounted in appropriate test fixtures for applying the simulated test loads and reactions. The sidewall heat shield will be installed in all test setups of the inner structure. The various test articles involved in the setups for each condition are as follows:

Test Conditions

Inner structure, aft heat shield
Inner structure
Inner structure, forward and sidewall heat shield
Inner structure, crew couch attachments in cabin
Inner structure, main parachute fitting on forward section
Inner structure, drogue parachute fitting on forward section
Inner structure
Inner structure, four simulated thrusters on forward section
Forward heat shield, four thruster fittings and tower attachments
Inner structure, aft heat shield
Inner structure, pilot chute mortar on forward section
Inner structure, drogue chute mortar on forward section

Strain gages and deflection devices will be installed on the test article before start of testing. Accelerometers will be installed for the natural frequency determination.

For all test conditions except as noted, the same general loading procedure will be followed and satisfactorily completed before change-over to the next test condition. The performance of the structure under test will be controlled by monitoring the appropriate instrumentation. If any load increment produces stresses or deflections which are considered excessive, the test will be terminated. The cause of this occurrence will be investigated before continuation of testing. In all cases, strain and deflection data will be recorded at each stabilized load increment.

Conditions 1 through 8. Load will be applied in approximately 10 equal increments to design limit (ultimate divided by 1.5) and relieved in the same increments to zero; a check will be made for permanent set. The test article will be reloaded to design ultimate in 15 equal increments.

Conditions 9 and 10. Load will be applied in approximately 15 equal increments to design ultimate and relieved in the same increments to zero; a check will be made for permanent set.

Conditions 11 and 12. Load will be applied in sufficient increments to establish spring rate but not to exceed design limit. Low level vibratory forces will be applied along the major axis of the pilot or drogue mortars to determine the natural frequency of each input load, and mortar accelerations will be measured and recorded.

12.3.2.3.1.6 Facilities and Equipment. The command module tests will be performed at the Space Science Development Facility of S&ID, Downey, California.

Ground support equipment for weight and balance determination, transport, and hoisting of the command module will be required.

Inaccessible instrumentation will be installed on the sidewall heat shield and cabin structures before final assembly by S&ID Manufacturing.

Strain, deflection, load and pressure transducers, and related recording equipment will be required for the static tests. Load links and accelerometers with related recording equipment will be required for dynamic test.

Hydraulic load struts, pressure regulating units, and jigwork for load and pressure application and reaction will be required for the static tests. A suitable vibration exciter with power supply and control equipment will be required for the dynamic test.

12.3.2.3.2 Command Module Static Structural Thermal Test (ATR 200-2)

12.3.2.3.2.1 Background Information. Under ATR 200-2, full-scale structural thermal verification tests will be performed on the spacecraft command module without ablator on the heat shield for the simulated overshoot trajectory. The performance of the over-all heat shield structural attachment system, as well as the interaction of the detailed subsystems will be evaluated. The integrity of the command module heat protection system depends upon the proper functioning of this strain isolation system which must allow gaps to close prior to maximum heat flux. The effects of an artificial slip-stringer constraint on gap-closure will also be determined.

These tests complement the room temperature load tests performed on the command module under ATR 200-1.

12.3.2.3.2.2 Test Article. A command module of spacecraft configuration less ablator on heat shield will be required. The ballast simulating the ablator on the heat shield, as well as other mass distribution not pertinent to the thermal test will be removed upon delivery to the test site. After the thermal tests are completed, these items will be reinstalled on the command module as required for the subsequent landing impact and stability tests.

12.3.2.3.2.3 Test Objectives. The thermal tests on the command module heat shield mounted on the inner structure are designed to meet the following objectives:

1. To perform full-scale design evaluation of the command module without ablator under conditions commensurate with the entry trajectories

2. To verify the performance of the over-all heat shield structural attachment system design and to ascertain the detailed interaction of the various slip joints and frames

3. To verify the structural and thermal analyses pertaining to the performance of the inner cabin heat protection as influenced by the attachment mechanisms and related insulating materials and installation clearances

[redacted]

12.3.2.3.2.4 Test Conditions. The test objectives will be satisfied by simulating the temperature time history for the appropriate test condition on the bare command module heat shield assembled on the inner structure. The thermal test requirements selected to determine the performance of the strain isolation system are presented as follows in testing sequence:

1. Condition 1 (heat shield calibration)

   The entire outer surface of the heat shield will be heated uniformly in a specified manner to a stabilized maximum temperature to determine the functional characteristics of the strain isolation system. These results will be used to evaluate the subsequent thermal tests.

2. Condition 2 (design proof)

   The heat shield will be cooled on selected +Z zones and then heated on the -Z zones in a manner which will give the required temperature distribution in each of the temperature control zones. This test simulates the thermal environment on the heat shield during entry following a lunar mission. The temperature time histories will be modified as needed for testing practicality. The response of the over-all heat shield and the strain isolation system will be measured and evaluated with Condition 1.

2. Condition 3 (malfunction)

   For this test the heat shield slip joints on opposite sides of the Z axis will be restrained from any movement. The heat shield will then be tested in the same way as for Condition 1. This test simulates an artificial condition wherein binding of the slip-joints is induced to determine the response of the over-all system.

12.3.2.3.2.5 Test Plan. Tests will be performed in the following sequence:

Condition 1 (heat shield calibration)
Condition 2 (design proof)
Condition 3 (malfunction)

[redacted]

[redacted] [redacted]

For all thermal tests, the command module will be mounted in a test fixture through the thermal pedestals at the tower attachments.

Thermocouples, strain gages, and deflection devices will be installed on the test articles before start of testing. The instrumentation will be measured and recorded as a function of time for each test condition. The performance of the command module during testing will be controlled by monitoring the appropriate instrumentation.

The command module will be completely surrounded and heated by a radiant heat oven which utilizes quartz enclosed tungsten filament infrared lamps installed in modular reflectors. The reflector lamps will be located about 5 inches from the heat shield surface. The oven will be independently supported to avoid contact with the command module exterior. If necessary, the surface of the heat shield will be coated with a lamp black solution to improve the heat transfer. Suitable instrumentation will be used to verify the gap between the heat shield and the oven.

Thermocouples will be installed at selected control points on the heat shield surface and will be centered on about 66 reflector zones. The temperature-time histories will be programmed on the radiant heating facility computers. The temperatures measured on the heat shield exterior will be fed back to the computer which will determine the heat flow required to maintain the test temperature. Additional thermocouples will be installed to measure the temperature on the backface of the heat shield, the slip attachments, and the inner structure. Provisions for cooling a specified heat shield sector on each side of the +Z axis will be incorporated in the oven setup for Condition 2.

Condition 1 (heat shield calibration)

Heat will be programmed for a linear temperature rise on the entire outer skin of the heat shield substructure to a uniform temperature in each of the heating zones. Deflections, strains, and temperatures will be monitored and recorded as a time function on suitable high-speed recorders. During testing, the

[redacted]

differential temperature between the front and back faces of the sandwich honeycomb heat shield will not exceed the specified thermal gradient at any time. Shutdown will occur when the noted gradient is reached, or after the test temperature is stabilized for five minutes. The heat shield will be inspected after test for any evidence of failure. If examination of data indicates that test was successfully completed, testing will proceed with test Condition 2.

Condition 2 (design proof)

The +Z sector on the heat shield will be cooled until the depressed test temperature is attained in the specified time. The temperature will be maintained while the -Z zones on the heat shield are heated in accordance with the programmed temperature rise until the maximum elevated test temperature is reached and stabilized. At this time, programmed heating will be started on the +Z sector, to be continued until the end of the specified test period. Data will be monitored and recorded in same manner as for Condition 1.

During testing, shutdown will occur if the temperature between the outer and inner skins of the heat shield exceeds the specified gradient, if the diametrical temperature differential is reached, if the upper limit of the maximum temperature tolerance is attained, or if binding of slip attachments is indicated. The test article will be inspected after test for evidence of failure. The data will be examined to verify that the strain isolation system operated properly before change-over to Condition 3.

Condition 3 (malfunction)

After the specified attachments are restrained in an approved manner against movement, the test procedure for Condition 1 will be followed. During testing the instrumentation will be closely monitored to preclude the propagation of the constraint beyond controllable levels. After test, teardown of the setup will not be started until inspection of the test article and examination of data are completed.

12.3.2.3.2.6 Facilities and Equipment. The command module thermal test will be performed at the Space Science Development Facility of S&ID, Downey, California.

Ground support equipment for weight and balance determination, transport, and hoisting of the command module will be required.

Inaccessible instrumentation will be installed on the command module before final assembly by S&ID Manufacturing.

12.3.3 <u>Service Module Structural Tests</u>

12.3.3.1 Component Tests

12.3.3.1.1 <u>Service Module Outer Shell Panel Test (ATR 301-1)</u>

12.3.3.1.1.1 Background Information. A structural test will be performed to evaluate a service module 60-degree panel for critical circumferential and longitudinal loadings of maximum $q\alpha$ condition.

12.3.3.1.1.2 Test Article. The test artical is a spacecraft service module outer shell, drawing DTT 6346. The test article, a 120-inch by 80-inch by 1-inch curved panel, consists of 5052H-39 aluminum honeycomb core bonded to 7178-T6 clad aluminum alloy facesheet.

12.3.3.1.1.3 Test Objectives. Test objectives are to determine strength, stress distribution, deflection characteristics, and failure mode, and to demonstrate design criteria.

12.3.3.1.1.4 Test Conditions. Ultimate combined loads test — Saturn V configuration.

Test loads consist of two concentrated end loads applied simultaneously with a uniform normal (pressure) load. The end load is reacted uniformly along reference station 197, and the pressure load is reacted along the edges of the panel tangent to the panel curvature.

12.3.3.1.1.5 Test Plan. The test article will be installed in a fixture capable of uniformly reacting the end panel close-out from the application of the concentrated loads. A hinge attachment along the panel length edge members will react the pressure load normal to the panel surface as applied by a hydrostatic bladder. Incremental loading to failure will be accomplished using simultaneous pressurization of hydraulic load struts and the hydrostatic bladder. The test article will be instrumented to provide strain and deflection data at design critical locations.

[redacted]

12.3.3.1.1.6 Facilities and Equipment. The test is to be conducted by Engineering Development Laboratories, Structural Test Lab, building 1, S&ID, Downey. Fixtures, supporting test hardware, and equipment to be fabricated or supplied by EDL are Edison load maintainers, hydraulic struts, automatic bridge balance and strain gage data acquisition system, pressure gages, strain and deflection transducers, test bed, and associated linkage.

12.3.3.1.2 Service Module Simulated Aft Bulkhead Test (ATR 301-3)

12.3.3.1.2.1 Background Information. The service module aft bulkhead is designed to support the SPS tanks and to resist hoop compression due to air loads at maximum q condition. The most critical condition for the aft bulkhead occurs at end boost when the tanks are applying g loads to the aft bulkhead.

An exact analysis of the aft bulkhead is impossible using existing structural methods. Approximate methods of analysis have been used, but a test is necessary to demonstrate the validity of the analysis.

12.3.3.1.2.2 Test Article. Simulated aft bulkhead, drawing DTT 6204. The test article consists of a 200-degree circular segment of a bonded aluminum honeycomb panel 3 inches in depth. The panel represents two auxiliary equipment bays and two adjacent propellant tank bays.

12.3.3.1.2.3 Test Objective. Evaluate the strength, stress distribution stiffness, stability, deflection characteristics, and failure mode. Verify the design and analysis and obtain data for design modification.

12.3.3.1.2.4 Test Conditions. Propellant tank inertia ultimate loads test. (Load magnitudes determined from test article capability.) Two concentrated loads, one at each tank location are to be distributed to the bulkhead at the lower tank skirt ring. Reaction boundaries will be comprised of simulated spacecraft S/M and adapter shell, S/M radial shear webs, and propellant tank skirts.

12.3.3.1.2.5 Test Plan. The test bulkhead together with the attached simulated spacecraft structure will be erected in a beam and column type load fixture. Incremental test loads will be applied as a compression load, through flat plates, on the tank skirts up to bulkhead failure. The test article will be instrumented to provide stress and deflection data at design critical locations. The supporting simulated spacecraft structure will be instrumented to determine load paths and magnitudes.

12.3.3.1.2.6 Facilities and Equipment. The test is to be conducted by the Engineering Laboratories, Structural Test Lab, S&ID, Downey. The simulated spacecraft structure is to be fabricated by the Apollo Manufacturing unit per drawing DTT 6267. Test bed and linkage, Edison load maintainers, a bridge balance and data acquisition system, and strain and deflection transducers are to be furnished by EDL.

12.3.3.1.3 Service Module Radial Shear Web Test (ATR 301-5)

12.3.3.1.3.1 Background Information. The radial beams are one of the major structural components of the service module. The beams are designed to distribute the command module loads and the SPS tank loads to the outer shell. For design considerations, the forward half of the radial beams is generally critical for the maximum $q\alpha$ phase of the mission due to high moments at the command module-service module interface. The aft end of the radial beams is subjected to critical loads during end boost flight condition, due to acceleration loads transmitted by SPS tanks.

A static structural test will be performed where the applied loads to the radial beams will induce realistic strains in the inner flange area and central and forward portions of the beam.

12.3.3.1.3.2 Test Article. Spacecraft service module radial beam 6, drawing V17-326001. The test article is machined with integral stiffeners, inner and outer caps, and truss, from a 7075-T6 aluminum alloy billet. A simulated equipment bay shelf is bolted to the web.

12.3.3.1.3.3 Test Objectives. Test objectives are to determine the structural integrity, stress distribution, deflection characteristics, and failure mode of the radial shear beam, and to evaluate the strength properties, stiffness, stability, and design configuration.

12.3.3.1.3.4 Test Conditions

Condition I (maximum q negative pressure and outward radial pad shear)
Condition II (maximum q negative pressure and inward radial pad shear)
Condition III (end boost stage I)
Condition IV (maximum q positive pressure and minimum outward radial pad shear)

[redacted]

In addition to the primary loads, defined by the test condition, vertical truss loads and aft bulkhead loads will be applied with each condition. The test loads will be reacted in shear at the aft bulkhead, along the outer beam cap and the forward bulkhead station.

12.3.3.1.3.5 Test Plan. The test beam will be erected horizontally in a beam and column structure. Jigwork, attached to the test article for load application, will consist of the following: a thin sheet lateral stabilizer bolted along the length of the beam inner cap, a whiffle tree and pad pressure distribution system along the beam outer cap, a two-component adapter block at the beam truss pad, and a slotted frame with whiffle tree bolted at the lower (aft bulkhead station) end. Load straps and calibrated hydraulic jacks will pick up load points on the aforementioned jigwork and react at the beam column structure. The radial beam reactions will be measured by load cells through a shear strap bolted along the outer cap, through structural steel angles bolted to the upper (truss end) cap, and through an extension of the legs of the slotted angle load frame at the aft bulkhead station. Jigwork weight will be counter-weighted, and thin sheet metal straps will provide lateral stability at the truss pad and at the center of the beam at the outer cap. Test loads and instrumentation, consisting of strain gages and defection transducers, are to be recorded at each load increment up to limit load for Conditions II, III, and IV, and up to ultimate load under Condition I.

12.3.3.1.3.6 Facilities and Equipment. The test to be conducted by Engineering Development Laboratories, Structural Test Laboratory, building 1, S&ID, Downey. Fixtures, supporting test hardware, and equipment to be fabricated or supplied by EDL are Edison load maintainers, hydraulic struts, automatic bridge balance and strain gage data acquisition system, pressure gages, strain and deflection transducers, test bed, and associated linkage.

12.3.3.1.4 <u>Friction Shear Joint Test, Service Module (ATR 301-7)</u>

12.3.3.1.4.1 Background Information. The friction shear test was initiated to ascertain the shear carrying capability of the service module type joints. The service module panels attach with screws at spacings of 2 inches along all radial beams and bulkheads. These holes are 1/16 inch oversize for the 1/4 pan head screws being used. Since holes are extremely oversize for ease of manufacturing assembly, the need for uniform stress distribution at load equal to or less than limit, requires a friction joint. The theory indicates that with adequate pretorquing of screws a high preload in the screw can enable the joint to sustain a shear load. The faying surfaces of service module joints have a finished surface between 125 RMS and 63 RMS, as well as various chemical surface treatments for corrosion prevention. Since both the above conditions effect the coefficient of friction, the specimens in the test will reflect the usage of different finish treatments, i.e., alodine, anodize, etc, that occur in accordance with the service module finish specification.

12.3.3.1.4.2 Test Articles. Plate Assembly — Shear Joint, DTT 6525. Two test articles are contained in each of eight assemblies. All parts of each assembly are to be surface finished by one of seven processes. The eighth assembly is to be bare.

12.3.3.1.4.3 Test Objectives. Test objectives are to determine the ability of selected surface finishes to transmit shear load and to compare the friction forces developed by Iridite, Alondine, and bare metal surfaces.

12.3.3.1.4.4 Test Conditions. The tension load will be uniform. Test plates will be reacted in shear. Sufficient tension load is to be applied to cause joint slippage.

12.3.3.1.4.5 Test Plan. The test articles will be installed in a universal test machine using suitable clevis fittings. Incremental loads, up to the inception of bolt bearing, will be applied and recorded. Relative motion between plates will be determined from dial indicator readings.

12.3.3.1.4.6 Facilities and Equipment. The test is to be conducted by Engineering Development Laboratories, Mechanical Properties Laboratory, building 1, S&ID, Downey.

12.3.3.1.5 <u>Circumferential and Longitudinal Edge Member Joint Tests Service Module (ATR 301-9)</u>

12.3.3.1.5.1 Background Information. The service module has shell joints which have major loads carried through them in both the circumferential and longitudinal directions. The circumferential or girth joint is loaded basically in compression through bolts on two-inch centers. This loading occurs at a maximum during the maximum $q\alpha$ condition and is contributed to by both body axial loads and body bending loads. The purpose of the joint is to redistribute the loads from the aft bulkhead lip to each face of the honeycomb shell. This loading is locally equivalent to applying a compression load plus a bending moment with the outer face sheet being loaded greatest. Since the joint elements to be tested are apart from the shell foundation, the resisting couple is to be taken by a shear load beneath the loading head. It is felt that if this joint can sustain the ultimate test load, the corresponding service module joint and others similar to it will have no problem as the test environment is conservative.

There will be three different configurations in this test. The basic is similar to the early service module design with doubler and dense-edge core terminating at the same point. The second specimen type has a doubler stepped in three places and a dense core offset 1/4 inch from the doubler termination. The third specimen type has the basic configuration but with a 1/4 inch dense core doubler offset. The stresses at the face-to-core location are theoretically smallest when the joint has been stepped and the core offset. The stresses are highest on the basic configuration.

The longitudinal joint to be tested is typical of most of the panel edges adjacent to the six radial beams in the service module. These joints are bolted to the beam flanges at a spacing of 2 inches and carry through them in the circumferential direction a shear, axial load, and bending moment. The maximum loads on the joint occur at the maximum $q\alpha$ condition and are due to dynamic loads on the RCS panel in addition to aerodynamic pressure loading. There are three basic configurations involved. The basic joint is similar to the spacecraft structure with doubler and dense-edge core terminating at the same location. The second specimen has a recess of 1/4 inch between doubler edge and core splice whereas the third specimen type has a 1.0 inch longer doubler beyond the core splice. The face-to-core stresses in these joints should vary considerably according to theory, and the test should corroborate this as well as demonstrate the adequacy of the early service module design.

12.3.3.1.5.2 Test Articles. Panel edge member, drawing DTT 6527. Panel circumferential joint, drawing DTT 6526. The test article consists of 7075-T6 aluminum honeycomb panels, 4 inches by 7 inches by 1 inch, with close-outs and various combinations of doublers, core densities, and face sheet thickness.

12.3.3.1.5.3 Test Objectives. Test objectives are to determine strength, stress distribution, and failure mode of the selected configurations anticipated for the spacecraft service module outer shell.

12.3.3.1.5.4 Test Conditions

Ultimate load	Tension with bending
Ultimate load	Compression with bending

12. 3. 3. 1. 5. 5 Test Plan. A universal testing machine will be used to apply edgewise loads incrementally to a solid bar close-out of the panel. A solid "T" section will react the panel through bolts to the close-out typifying spacecraft configuration. Strain gages, deflection gages, and photostress plastic will be used to determine load paths and strain distributions.

12. 3. 3. 1. 5. 6 Facilities and Equipment. Tests are to be conducted by the Engineering Development Laboratories, Mechanical Properties Laboratory, S&ID, Downey.

12. 3. 3. 1. 6 Aft Bulkhead Structural Components Tests, Service Module (ATR's 304, 304-1, 304-2)

12. 3. 3. 1. 6. 1 Background Information. The major load in the aft bulkhead is the inertia force of the SPS tanks. This load is distributed by the aft bulkhead into the radial beams and the outer shell.

At the connection of the tank to the bulkhead there will be local stress concentration in the honeycomb core. A test is required to determine the amount of stress concentration.

Another difficult interface is the connection of the bulkhead to the radial beams. High shear and bending stress plus the possibility of peeling complicates the analysis of this joint. Three different joints will have to be tested to determine the most efficient connection. When the final joint is chosen a test must be run to verify the design.

12. 3. 3. 1. 6. 2 Test Articles.

Test panel honeycomb junction	Drawing DTT 6207
Test panel honeycomb section	Drawing DTT 6410
Bulkhead panel section	Drawing DTT 6530

Drawings DTT 6207 and DTT 6410 are of varied configurations of the service module aft bulkhead splice at the radial shear beam junction between the service module fuel and oxidizer bays.

Test article DTT 6530 represents the fuel and oxidizer tank skirt lower attachment to the aft bulkhead on each side of the radial shear beam junction but excludes the panel splice.

12. 3. 3. 1. 6. 3 Test Objectives. Test objectives are to obtain strength data for design selection and to determine failure modes.

[redacted]

12.3.3.1.6.4 Test Conditions. Specimen will be loaded to failure. Test loads will be applied to produce maximum beam shear and maximum bending moment.

12.3.3.1.6.5 Test Plan. The test articles will be installed in a universal test machine. Test articles DTT 6207 and DTT 6410 will be set up as a single span, simple support with concentrated load at the midpoint of the span. For test article DTT 6530, a rod and bearing pad will be used for the application of a compression load.

Deflections and loads will be measured and failure modes will be determined.

12.3.3.1.6.6 Facilities and Equipment. Tests are to be conducted by the Engineering Development Laboratories, Mechanical Properties Lab, building 1, S&ID, Downey.

12.3.3.1.7 Static Structural Tests: Joints (ATR 309-2)

12.3.3.1.7.1 Background Information. This test is a development test designed to obtain design allowables for various types of joints in honeycomb.

A large percentage of the service module and command module structure is made of bonded aluminun honeycomb construction. The attachments to the honeycomb present many problems. There is a lack of good design allowables, and analytical methods are insufficient to give design values; therefore, a test must be performed.

In general two types of joints are of particular concern:

1. Joints with large loads where it is necessary to grip both face sheets
2. Joints that are supporting light loads and attach to one face sheet only to save weight

12.3.3.1.7.2 Test Articles. Panel drawing DTT 6569. The test articles consist of 2014-T6 aluminum honeycomb panels 6 inches by 6 inches by depths of 1/2, 1, and 3 inches, with various combinations of core densities and face sheet thicknesses. Joint configurations were made up of bonded tees, riveted and bolted clip angles, channels, and inserts attached to the panels.

12.3.3.1.7.3 Test Objectives. Test objectives are to determine design allowables and ultimate load carrying capabilities for joint configurations to be used on the spacecraft service module outer shell.

12.3.3.1.7.4 Test Conditions. Ultimate load tests will be as follows:

- Bolt tension
- Bolt tension and bending
- Bolt shear and bending
- Bolt tension, shear, and bending
- Rivet tension
- Rivet tension and bending
- Rivet shear and bending
- Bond shear

12.3.3.1.7.5 Test Plan. A universal testing machine will be used to apply continuous singular load to clips and bolts, with the panel reacting through a ring frame plate up to joint failure. Load versus head travel will be autographically recorded.

12.3.3.1.7.6 Facilities and Equipment. Test to be conducted by Engineering Development Laboratories, Mechanical Properties Laboratory, building 1, S&ID, Downey.

12.3.3.1.8 <u>Service Module Honeycomb Panel Thermal Tests.</u>

12.3.3.1.8.1 Background Information. Elevated temperature panel tests will be performed to determine ultimate strength (local instability) of each of the two types of outer shell structure, radiator and basic shell. Test data will be used to determine realistic material allowables for the elevated temperature environment existing at end boost first stage.

12.3.3.1.8.2 Test Article. Twelve flat panels, 10 inches by 10 inches by 1 inch will be tested. Six panels will be fabricated similarly to the radiator portion of the outer shell:

Outer face sheet	0.030 inches thick, 6061-T6
Inner face sheet	0.016 inches thick, 7178-T6
Core	0.25 by 0.001 inch, 5052-H39

Six panels will be fabricated similar to the basic portion of the outer shell:

Outer face sheet	0.016 inches thick, 7178-T6
Inner face sheet	0.016 inches thick, 7178-T6
Core	0.25 by 0.001 inch, 5052-H39

[redacted]

12.3.3.1.8.3 Test Objectives. Test objectives are to determine short exposure time strength properties of the outer shell honeycomb structure.

12.3.3.1.8.4 Test Conditions. Each of the two panel types will be tested under uni-axial loading at room temperature and also at the predicted end boost first-stage temperature. Although heat input rates are similar for both the radiators and basic shell, differences in outer face sheet thicknesses result in different flight temperatures.

12.3.3.1.8.5 Test Plan. Tests on the radiator type panels (with 6061-T6 outer face sheet) will be performed at room temperature and at 250 F. The basic panels (both face sheets of 7178-T6) will be tested at room temperature and at 375 F.

Three panels of each of the two types will be tested at predicted flight temperatures and three of each type at room temperature, for control. Tests will be performed as follows:

1. Uniformly distributed uni-axial compression load will be applied to ultimate design stress level.

2. Temperature of test article will be increased linearly during a two-minute period. Heat will be applied to both sides of the test article.

3. Immediately after the two-minute heating period, the applied load will be increased to failure. Load will be increased at a rate of approximately 2 percent per second. Test temperature will be maintained until failure occurs.

Applied load, test article temperature, and strain will be recorded continuously as a function of test time during each elevated temperature test. Continuous recording of test article temperature during room temperature testing is not required.

12.3.3.1.8.6 Facilities and Equipment. The service module honeycomb panel thermal panel tests will be performed at the Space Science Development Facility of S&ID, Downey, California.

Strain, temperature, and load transducers with applicable recording equipment will be required for data acquisition and monitoring application of test environment. Radiant heat lamp ovens and associated power and control equipment will be required for application of thermal environment.

12.3.3.2 Sub-Assembly Tests

12.3.3.2.1 SPS Main Propellant Tank Cover Door Test (ATR 301-8).

12.3.3.2.1.1 Background Information. The SPS main propellant tank cover door is a major structural component of the basic tank unit and behaves as a close-out for containing fuel and oxidizer fluids under pressure. The door design considerations were based on the same flight conditions as the propellant tanks, primarily during the boost phase. Further design criteria stem from the preflight SPS system testing requirements.

The structural test, required to verify the integrity of the door assembly, will involve a pressure vessel fixture that gives more rigid boundary conditions than does the spacecraft vessel. The configuration of the test vessel is required from a safety standpoint, and will result in a more severe loading effect on the door. The roll-swaged joints at the piping-door interface will be evaluated structurally for piping deflections induced by tank expansion.

12.3.3.2.1.2 Test Article. Door Oxidizer Sump Tank, drawing VI7-470210. The test article is a 6AL-4V titanium access door, for the spacecraft nitrogen tetroxide sump tank, with shortened sections of standpipe, column, and external piping.

12.3.3.2.1.3 Test Objectives. Test objectives are as follows:

1. Prove the structural integrity of the spacecraft design configuration.

2. Determine stress distributions, deflections characteristics, permanent set and location and mode of failure.

3. Evaluate the associated pipe assemblies and roll-swaged joints.

12.3.3.2.1.4 Test Conditions.

Proof pressure, leakage
Limit pressure, static
Limit pressure, cyclic
Burst pressure and failure

Test loads consist of pressure based on a 240 psig design limit load and piping forces, imposed during test by deflecting pipe ends, equivalent to forces resulting from piping bracketry restraint and tank expansion in the spacecraft configuration.

[redacted]

12.3.3.2.1.5 Test Plan. The test door will be installed on a 40-inch diameter spherical test tank using two rubber O-ring seals. A hydraulic jack mechanism will attach through pinned collars to the free ends of each of two main pipes. The test tank will be hydraulically pressurized using distilled water.

The test door will be subjected to incremental pressure and pipe deflections.

Stresses, strains and deflections will be determined by photoelasticity, strain gages, and deflection transducers at each increment during the limit pressure test and the burst pressure test. Continuous cyclic pressurization at qualification levels and durations will be simultaneous with applied pipe deflections.

12.3.3.2.1.6 Facilities and Equipment. The test is to be conducted by Engineering Development Laboratoies, Pressure Test Facility, building 56, S&ID, Downey.

Equipment to be supplied by EDL consists of two hydraulic pumps, a pressure cyclic console, hydraulic strut pressure gages, bridge balance and channel selector data system, strain and deflection transducers, LF/Z, OI/Z meters, and photographic equipment for photoelastic studies.

12.3.3.2.2 <u>Pressure Vessel Tests — Service Module Pressurant and Propellant Tanks (ATR 302-1)</u>

12.3.3.2.2.1 Background Information. The service propulsion system (SPS) utilizes pressure vessels for fuel, oxidizer, and pressurant storage. Pressure loads are exerted on the vessel shells during the mission while accelerations that occur during the boost phase of the mission, introduce loads into the vessel supporting structures and the lower domes of the vessels. During SPS engine firing, non-uniform thrust chamber pressure promotes the formation of the shock waves at the nozzle exit, thus introducing a continuous vibration mode in the spacecraft. Additional shock forces emanate from surge pressures identified with instability of propellant mixtures.

The SPS vessels during the mission will be exposed to several combinations and superimpositions of the loads described. The most critical of these conditions have been selected to establish the design criteria for the vessels. In order to confirm the structural integrity of the vessels consistent with the above requirements, a series of structural tests is necessary. The test loads will reflect the design conditions within the framework of structural testing capabilities.

12.3.3.2.2.2 Test Articles

Oxidizer Tank	Main propellant assembly, drawing V17-342002
Fuel Tank	Main propellant assembly, drawing V17-343002
Helium Tank	Main propellant assembly, drawing V17-347002

The test articles are Block I spacecraft configuration. The propellant tanks are cylindrical, hemispherically domed, with an access door in the lower dome. The oxidizer tank is 51-inch ID approximately 165.4 inches in length. The fuel tank is 45 inches ID and approximately 166.8 inches in length. The spherical pressurant tank is 40 inches inside diameter with integral bosses.

12.3.3.2.2.3 Test Objectives. Test objectives are as follows:

1. Evaluate the design of the SPS pressure vessels when subjected to internal pressure and inertia load

2. Determine stress distributions, deflection profiles, volume change, permanent set, and location and type of failure

3. Demonstrate that the structures neither yield at proof pressure nor rupture at burst pressure

4. Demonstrate that the pressurant tank will sustain limit inertia load with ultimate pressure without failure and that the propellant tanks will sustain inertia load with limit ullage pressure without failure

5. Determine the dynamic characteristics of the vessels with respect to the predicted service environment

12.3.3.2.2.4 Test Conditions

Pressurant Tank

Condition I	End boost stage I
Vibration A	Sinusoidal resonance search
Vibration B	Random vibration spectrum

[redacted]

Propellant Tanks

Condition I	End boost stage I
Condition II	Midcourse correction
Vibration I	Sinusoidal sweep

12.3.3.2.2.5 Test Plan. Pressurant tanks will be oriented in the launch position and restrained by a test fixture at the tank bosses to simulate spacecraft mounting. A strap around the midsection and hydraulic jacks will be used to apply the external load in conjunction with internally applied hydrostatic pressure. Stresscoat, strain gages, and linear potentiometers will be used to determine stresses and deflections. Instrumentation data will be automatically and continuously recorded.

Propellant tanks will be oriented in the launch position and mounted with the lower skirt bolted to a simulated service module aft bulkhead. The upper tank skirt will be laterally supported. Test conditions I and II will be performed by continuously pressurizing the tank to proof pressure with continuous recording of strain gages and deflection indicators. Pressure will be relieved and permanent deformation determined. Test condition I will be continued by repressurizing to limit ullage pressure and applying increased pressure on the lower dome by means of an internal piston. This will impose a simulated inertia load on the lower tank dome and skirt. Loading and recording of strain gages and deflection gages will be terminated at ultimate load. Test condition II will be continued by applying continuous pressure up to burst pressure, holding pressure for three minutes and then proceeding to failure pressure. All instrumentation will be continuously recorded to the time of failure.

Two tanks, filled with helium to limit pressure, will be rigidly mounted at the tank bosses and subjected to a sinusoidal vibration spectrum and a random vibration spectrum on an electromagnetic shaker in each of two tank axes.

Four tanks, filled with fluids that approximate the densities of the propellants and pressurized to limit pressure, will be subjected to a sinusoidal vibration spectrum on an electromagnetic shaker in each of three tank axes.

Pressurant and propellant tank input and response accelerations and dynamic strains will be continuously recorded.

12.3.3.2.2.6 Facilities and Equipment. Propellant tank tests are to be conducted by the Allison Division of General Motors Corporation, Indianapolis, Indiana. Pressurant tank tests are to be conducted by the Airite Division of Electrada Corporation, Los Angeles, California.

Burst test facilities, including fixtures, instrumentation, automatic data acquisition systems and test tanks are to be supplied by the subcontractors. North American Aviation, S&ID, Downey, will furnish simulated bulkheads, spacecraft propellant tank access doors, plumbing, and seals.

12.3.3.2.3. Static Test of the Service Module RCS Engine and Tank Supports with Service Module Panels Structure (ATR 308).

12.3.3.2.3.1 Background Information. Maximum $q\alpha$ flight condition is the most critical design consideration for the RCS panel assembly structure. Loads encountered during this phase are caused by aerodynamic excitation of the RCS engine panel, and consist of high dynamic and steady-state forces exerted in all directions on the panel mounted masses. These loads applied to the panel produce critical bending moments, shears, and axial loads in the panel, engine housing, and bracketry structures, while at the attachment points of the bracketry, the panel is critical for core-shear as well as face-sheet stress.

12.3.3.2.3.2 Test Article. Service module reaction control system panel assembly, Drawing No. V17-332101-201.

The test article consists of a 65 by 35 by 1 inch service module panel of 717B-T6 aluminum face sheets and 5052-H39 honeycomb core, propellant tank and helium tank bracketry, and an RCS engine housing.

12.3.3.2.3.3 Test Objectives. The objectives of this test are to verify the structural integrity of the design configuration and confirm the analysis for the RCS panel assembly; and to determine strength, stress distribution, and deflection characteristics of the engine housing, tank bracketry, and panel structure in the local area of the engine housing.

12.3.3.2.3.4 Test Conditions.

Condition 1 - Radially inboard nozzle loads with aft tank loads (limit)

Condition 2 - Lateral nozzle and tank loads (limit)

Condition 3 - Aft and lateral nozzle and housing loads and radially outboard tank loads (limit)

[redacted]

Condition 4 - Aft and lateral nozzle and housing loads and radially inboard tank loads (ultimate)

Panel loads consist of reactions from loads applied to the tank bracketry and engine housing. The panel loads are reacted through fixed supports bolted to the panel along both longitudinal edges.

12.3.3.2.3.5 Test Plan. The test panel will be installed in a fixture that will react the panel along two longitudinal edges of the panels. Loads will be applied through hydraulic jacks to the simulated tanks and simulated engine nozzles. Load-lever distribution systems will apply a uniform compression load to the engine housing. At each increment of load, strain gages and deflection indicators will be recorded, and stress concentration areas, as indicated from a birefringent coating on the panel surface, will be determined. The test will proceed to ultimate loads under condition 4 loading and then it will proceed to failure.

12.3.3.2.3.6 Facilities and Equipment. The test is to be conducted by the engineering development laboratory (EDL), structural test lab, building No. 1, S&ID, Downey.

The fixtures and equipment are to be supplied by the EDL and consist of hydraulic jacks, an Edison load maintainer, an automatic bridge balance, a strain gage data acquisition system, strain and deflection transducers, a test bed and associated load-lever distribution linkage, LF/Z and OI/Z meters, and photographic equipment for photo-elastic studies.

12.3.3.3 Complete Assembly Tests

12.3.3.3.1 Structural Tests of Service Module to Command Module Fairing (ATR 300).

12.3.3.3.1.1 Background Information. The tests performed under ATR 300 will evaluate the structural integrity of the service module to command module fairing for critical boost-phase differential pressure environment and fly-away umbilical disconnect separation loads.

The fairing between the command module and the service module is basically loaded by the difference between the vent and external aerodynamic pressures. A pressure seal exists between the service module fairing and the heat shield. The seal prevents excessive venting and maintains a net bursting pressure inside the service module. The critical areas of the fairing are the outer aluminum face sheets and the legs of the vertical splices between the six equal bays. The outer face area on the fiberglass tip as well as the splices in the circumferential direction are also critical for hoop tension loads.

The effects of the fly-away umbilical set by actuation of the pneumatic pistons, in addition to the pivot arms, will also be evaluated. The test structure will be composed of the fairing with cutout, edge-reinforced with a Z-frame. A plate is attached to the Z-frame. On the spacecraft, the fly-away set may be disconnected in two ways. The first situation occurs when four pneumatically operated push-off pistons are actuated. If these pistons fail to cause the separation, two pivot arms, actuated mechanically by a rope, will push the set away. Critical loading will occur when the two separation methods are acting together. Under these conditions, the ultimate loading will consist of four piston loads pushing radially inward and two arm loads also pushing radially inward. These loads are in line horizontally at service module station 365.5.

12.3.3.3.1.2 Test Article. The test article will consist of spacecraft configuration service module to command module fairing. No ablative covering or non-structural systems will be installed. Service module ring frame (V17-320103) will be used to achieve spacecraft configuration boundary conditions. Stiffness simulation of forward bulkhead is not required.

12.3.3.3.1.3 Test Objective. The objective of this test is to evaluate the structural integrity of the service module to command module fairing for critical boost phase differential pressure environment and fly-away umbilical disconnect separation loads.

12.3.3.3.1.4 Test Conditions. The test objectives will be satisfied by subjecting the service module to command module fairing to the following conditions of static loads and pressures.

Test Condition I - Structural Integrity of Service Module to Command Module Fairing for Fly-Away Umbilical Disconnect Separation Loads. This condition will evaluate the fairing assembly for loads induced by separation of the fly-away umbilical disconnect. The test article will be subjected to static loads representative of umbilical separation by normal pneumatic system (GN_2) and the backup lanyard system acting simultaneously.

[redacted]

Test Condition II. Structural Integrity Evaluation of Service Module to Command Module Fairing for Boost Differential Pressure Environment. This condition will evaluate the fairing assembly for a positive internal pressure condition which occurs during boost.

A uniform bursting pressure will be applied to the entire inner surface of the test fairing assembly. No thermal environment or concentrated external loads will be applied.

12.3.3.3.1.5 Test Plan. Tests will be performed in the following sequence.

1. Condition I, limit level (structural integrity of service module to command module fairing for umbilical separation loads)

2. Condition II, limit level (structural integrity evaluation of service module to command module fairing for boost differential pressure)

3. Condition II, ultimate level (structural integrity evaluation of service module to command module fairing for boost differential pressure)

4. Condition I, ultimate level (structural integrity of service module to command module fairing for umbilical separation loads)

The fairing assembly will be evaluated for limit level condition I and II loads prior to ultimate level tests. Where practical, instrumentation for all test conditions will be installed prior to condition I test.

Test Condition I — Limit Level (Structural Integrity of Service Module to Command Module Fairing for Umbilical Separation Loads). The service module to command module fairing assembly will be mounted to the static test facility simulating the service module fairing interface. Design limit loads will be applied in five equal increments to specified magnitudes. Loads will be applied simultaneously through the simulated disconnect housing assembly for critical separation condition. Instrumentation data will be recorded at each stabilized load increment.

Test Condition II — Limit Level (Structural Integrity Evaluation of Service Module to Command Module Fairing for Boost Differential Pressure). The pressure bag fixture will be designed and tailored such that internal pressure may be simulated over 100 percent of the fairing inner face sheet.

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Design limit pressure will be applied in five equal increments to limit pressure value (approximately 7.25 psi). Instrumentation data will be recorded at each stabilized pressure increment. No concentrated external loads will be applied to the fairing assembly during condition II tests.

Test Condition II — Ultimate Level (Structural Integrity Evaluation of Service Module to Command Module Fairing for Boost Differential Pressure). Limit level tests will be repeated to ultimate level pressure magnitudes.

Test Condition I — Ultimate Level (Structural Integrity of Service Module to Command Module Fairing for Umbilical Separation Loads). Limit level tests will be repeated to ultimate level loads.

12.3.3.3.1.6 Facilities and Equipment. The service module to command module fairing tests will be performed at the Space Science Development Facility of S&ID, at Downey, California.

Strain, deflection, pressure, and load transducers with applicable recording equipment will be required for data acquisition, and monitoring application of loading environments.

The following special test fixtures will be required.

1. Service module ring frame (V17-320103) will be used to achieve spacecraft configuration boundary conditions. The test fixture will have provisions for mounting all structures (brackets, cables, etc.) which are affixed to both the fairing and forward bulkhead. Stiffness simulation of the forward bulkhead will not be required.

2. A pressure bag fixture will be installed on the basic fixture for simulation of positive internal pressure acting on the fairing. The fixture will be capable of simulating uniform burst pressure (ultimate level) over the entire surface of the fairing.

12.3.3.3.2 <u>SPS Structural Stiffness Evaluation (ATR 300)</u>.

12.3.3.3.2.1 Background Information. Service propulsion engine mount stiffness testing performed under ATR 300 is intended to generate engineering information which is required for the purpose of properly evaluating Apollo space flight performance and stability characteristics. An adequately confirmed assessment of the stiffness properties of the engine mount and service module structure must be achieved through

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physical testing in combination with and supplemented by theoretical analyses. Such a program will provide a reliable foundation on which the various dynamics analysis requirements may be based. The dynamics analyses will evaluate engine control motions and thrust vector deviations resulting from feedback system modulation initiated by perturbations due to the sloshing of fluids, motions of astronauts, and other mass displacements which affect the center-of-gravity position during thrust action. Thrust vector deviations also are produced by the thrust force acting upon unsymmetrical structural and mechanical systems.

Whether the effects of such disturbances are immediately convergent toward stable equilibrium, or whether divergency and catastrophic failure occurs, or some intermediate status exists, is dependent upon the interaction of structural and mechanical system stiffness and electrical system reaction capabilities. The speed with which thrust vector dispersions are damped out determines the efficiency of propellant utilization. Optimization of this characteristic is a primary objective in spacecraft design.

12.3.3.3.2.2 Test Article. The test article will consist of a spacecraft configuration service module with SPS gimbal ring and actuators installed. A rigid dummy engine fixture will be installed for application of unit test loads and moments.

Tests will be performed with the service module mounted to a fixture at the command module interface by simulated spacecraft-connecting hardware.

12.3.3.3.2.3 Test Objectives. The test series outlined below has been formulated to determine the structural stiffness of the service propulsion system engine mounts and the supporting service module structure.

12.3.3.3.2.4 Test Conditions. The test objectives will be satisfied by subjecting the service module to unit static loads and moments.

Unit static loads in +X and -X, +Y and -Y, and +Z and -Z directions and unit bending moments in $+M_y$ and $-M_y$, and $+M_z$ and $-M_z$ directions will be applied through the SPS spacecraft engine center-of-gravity location. Deflections and rotations of the SPS spacecraft engine center-of-gravity will be determined relative to the spacecraft center-of-gravity.

12.3.3.3.2.5 Test Plan. The two oxidizer tanks and two fuel tanks of the service propulsion system will be simulated. Interface configuration and empty weight (lateral reaction) at the forward bulkhead and aft bulkhead, and stiffness in bending between the bulkheads are the simulation requirements. The simulated tanks will be designed for ultimate level static load

[redacted]

tests to be performed at a later date. The service module will be installed in the vertical static test facility for moment and X, Y, and Z direction tests. The test facility will have provisions for fixing the service module to the fixture at the radial beam trusses, applying specified loads and moments to the SPS engine fixture, and applying a preload to develop the tension field effect in the radial beams. The preload will be applied along the X axis of the engine fixture.

All static loads and bending moments will act through the SPS spacecraft engine center-of-gravity.

Test static load and bending moment magnitudes will be applied and relieved in five equal increments. Moments will be applied as couples. The preload will be applied and held through all condition I tests. All gages will be zeroed in after preload is applied.

Static loads in the ±X, ±Y, and ±Z directions will be performed by incrementally applying a specified positive direction load; incrementally relieving an applied load to zero and increasing in a negative direction to a specified value; relieving an applied load to zero to complete one cycle; and performing a total of three loading cycles. Instrumentation data will be recorded at each stabilized load increment.

The bending moment tests in the $\pm M_Y$ and $\pm M_Z$ direction will be performed in a similar manner to the static load tests. Three incremental positive/negative cycles will be performed and data will be recorded at each stabilized increment.

12.3.3.3.2.6 Facilities and Equipment. The service module static tests will be performed at the Space Science Development Facility of S&ID, at Downey, California.

Deflection and load transducers with applicable recording equipment will be required for data acquisition, and monitoring application of loading environments.

The following special test fixtures will be required.

1. The two oxidizer and the two fuel tanks of the SPS will be simulated. Interface configuration at the forward and aft bulkheads, and stiffness in bending between the bulkheads are the simulation requirements.

[redacted]

2. The SPS engine fixture will have provisions for attachment to the engine mounting strut assemblies, attachment to the pitch actuator, and application of the test loads through the SPS spacecraft engine center-of-gravity. The engine fixture will also be designed for use in thrust-load structural evaluation tests to be performed at a later date.

3. The service module test facility will have provisions for fixing the service module to the fixture at the radial beam trusses, applying specified loads and moments to the SPS engine fixture and applying a preload to develop the tension field effect in the radial beams.

12.3.3.3.3 <u>Service Module RCS Unit Load Strain/Deflection Survey (ATR 300)</u>.

12.3.3.3.3.1 Background Information. The service module will be subjected to high dynamic loadings in the reaction control system area. The loads will be in the radial, tangential, and longitudinal directions due to the aerodynamic excitation of the RCS engine housing, and will be greatest during the maximum $q\alpha$ condition. These loads generate large shell bending moments and shears due to being applied at points away from bulkhead or radial beam. The possible combination of loads, i.e., the various directions, are quite varied.

The dynamic loads applied in the RCS panel area cannot be qualified on any dynamic test vehicle prior to flight test and will therefore be evaluated on the service module as quasi-static loads. It is impractical to test the many critical conditions that exist, so an influence coefficient test will be performed. This approach can be readily expanded by superposition to check the more critical conditions and therefore check for adequate strength in the various shell locations. The deflection information will be processed by system dynamic personnel to re-evaluate the magnitude of present inertia values in view of realistic stiffness information.

12.3.3.3.3.2 Test Article. The tests will be performed on a spacecraft configuration service module structure. The RCS modular panels will be structurally complete with tankage mounting brackets, and provisions for installing the engine housing.

12.3.3.3.3.3 Test Objectives. The test series outlined below has been formulated to obtain data for establishing a strain and deflection matrix of influence coefficients for analysis of the RCS vibration loading environment.

12.3.3.3.3.4 Test Conditions. The service module will be subjected to twelve loading conditions. A unit load will be applied to the service module at four locations: the engine housing attachment and tankage of sector II; and the engine housing attachment and tankage of sector III. The unit loads will be applied in three directions (radially, longitudinally, and tangentially) at the four locations for a total of twelve loading conditions. The sign of the applied loads (inboard or outboard, etc.) will be chosen for convenience of test set-up.

12.3.3.3.3.5 Test Plan. Tests will be performed with the service module mounted vertically in the basic test set-up of the combined module static test. Applied unit loads will be reacted at the command module interface and at the adapter interface.

Engine housing loads will be applied to the shell through a fixture using the housing to shell connecting hardware. Tankage loads will be applied such that the force is distributed by relative weight of the full fuel tank and weight of the full oxidizer tank. The weight-ratioed tank loads will act through the centers-of-gravity of each of the two tanks.

Strain and deflection data will be recorded for each of the twelve loading conditions.

12.3.3.3.3.6 Facilities and Equipment. The service module RCS unit load tests will be performed at the Space Science Development Facility of S&ID, at Downey, California.

Strain, deflection, and load transducers with applicable recording equipment will be required for data acquisition, and monitoring application of static loads.

12.3.4 <u>Spacecraft LEM Adapter Structural Tests</u>

12.3.4.1 Component Tests

12.3.4.1.1 <u>Spacecraft LEM Adapter, (SLA) Structural Elements; Thermal Tests (ATR 402-1).</u>

12.3.4.1.1.1 Background Information. Elevated temperature panel tests will be performed to evaluate thermal effects on the ultimate strength of the SLA shell section. Test data will be used to determine realistic material allowable for the elevated temperature environment existing at the end of boost of the first stage.

12.3.4.1.1.2 Test Articles. Panel Drawings DTT 6703 and DTT 6704. The test articles will consist of 2024-T86 aluminum honeycomb panels 12 by 12 by 1.7 inches with .25 by .001 inch and .125 x .001 inch cores and .02 inch face sheets.

12.3.4.1.1.3 Test Objectives. The objective of this text is to determine the ultimate strength and stress distribution of bonded aluminum honeycomb elements when subjected to uniaxial compression and specified thermal environments.

12.3.4.1.1.4 Test Conditions. The test will be conducted at ultimate load at room temperature, 300 F, 350 F, and 400 F.

12.3.4.1.1.5 Test Plan. A universal testing machine will be used to apply uniform compressive loads to the panel through a ball-joint compression fixture. Radiant heat lamps will supply thermal inputs to both face sheets. Strain gages and thermocouples will measure surface stress distribution and temperature variations.

12.3.4.1.1.6 Facilities and Equipment. The test is to be conducted by S&ID at Tulsa, Oklahoma.

12.3.4.2 Deleted

12.3.4.3 Complete Assembly Tests

12.3.4.3.1 <u>Spacecraft LEM Adapter Static Tests (ATR 404).</u>

12.3.4.3.1.1 Background Information. The tests performed under ATR 404 will evaluate the structural integrity of the spacecraft LEM adapter structure for critical boost phase-loading environments. Stiffness evaluation tests will also be performed to determine structural deflections under unit axial compression loads, torsion, and bending moments.

Critical combinations of aerodynamic and inertia loads, and differential pressure exist for the spacecraft LEM adapter at two time points during boost phase: maximum $q\alpha$, and end boost first stage.

The maximum $q\alpha$ condition will apply the maximum airloads to the test article. In addition, the design body loads and inertia loads will be applied. The maximum temperature on the structure for this condition is approximately 150 F. Since the design temperature is relatively

[redacted] [redacted]

low, and the time at temperature is short (60 seconds) there will be practically no loss in strength of the structure due to temperature, so the test will be run at room temperature.

The end boost condition has no airloads, and the body loads produce lower stresses in the structure than the maximum $q\alpha$ condition. The maximum temperatures in the shell skin for this condition, however, will be approximately 510 F, with no insulation, so the allowable skin stresses will be reduced.

Analytically, the maximum $q\alpha$ condition will be more critical than the end boost condition. The higher stresses for the maximum $q\alpha$ condition with room temperature allowables, are more critical than the lower stresses for the end boost configuration with the reduced allowables at 510 F.

From the room temperature end boost condition test, strain-gage data and deflection data will be obtained to determine the stress distribution on the test article.

A separate series of component tests (reference ATR 402-1) will be run on the shell structure to determine the allowable stresses at design temperature. A comparison of the stresses on the test article with the allowable stresses from the component tests, will permit an analytical determination of margin of safety for the end-boost condition.

12.3.4.3.1.2 Test Article. The test article will consist of a spacecraft configuration spacecraft LEM adapter structure. No ablative covering or non-structural systems will be installed.

In order to accurately simulate spacecraft boundary conditions, transition sections simulating the service module and the S-IVB instrument unit will be used for application and reaction of static load at the structural interfaces. Internal loads caused by inertia of the LEM vehicle will be applied through a fixture which simulates stiffness of the LEM and interface configuration at the adapter.

12.3.4.3.1.3 Test Objectives. The test series outlined below has been formulated to evaluate the structural integrity of the spacecraft LEM adapter for critical boost phase flight environments of aerodynamic and

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inertial loads, and differential pressure; and to verify analytical rigidity analysis of the adapter structure, and analytical stress and loads analysis of the adapter structure.

12.3.4.3.1.4 Test Conditions. Primary test objectives will be satisfied by subjecting the spacecraft LEM adapter to conditions of static load and pressure which simulate critical flight conditions of Saturn V boost.

Secondary objectives will be satisfied by subjecting the adapter to unit load/deflection tests.

Test Condition I — Stiffness Evaluation. Prior to structural integrity evaluation tests the test article will be subjected to unit bending moment, torsion, and static longitudinal compression loads. Deflections will be measured as a function of applied torsion, moment, and load.

Test Condition II — Maximum $q\alpha$. The adapter section will be subjected to static loads and differential pressures simulating the loading environment of Saturn V boost, maximum $q\alpha$ condition with LEM vehicle on board.

Test Condition III — End Boost First Stage. The adapter section will be subjected to static loads simulating the loading environment of Saturn V boost and end boost first stage condition with LEM vehicle on board.

12.3.4.3.1.5 Test Plan. Tests will be performed in the following sequence.

1. Test condition I (stiffness evaluation)

2. Test condition II, limit level (maximum $q\alpha$)

3. Test condition III, limit level (end boost first stage)

[redacted] [redacted]

4. Test condition III, ultimate level (end boost first stage)

5. Test condition II, ultimate level (maximum q α)

Weight and center-of-gravity of test article and fixtures will be determined prior to testing. All tests will be conducted at room temperature.

Test Condition I Stiffness Evaluation. The stiffness evaluation tests will be performed in four phases. All loads and moments will be applied and relieved incrementally. Phase 1 will consist of unit axial loading at the service module interface; phase 2 will consist of unit axial loads applied to the LEM interface; phase 3 will consist of unit bending moment applied as a couple at the service module interface; and phase 4 will consist of unit torsion applied as a couple at the service module interface.

Test Condition II Maximum q α. Service module interface axial load, shear load, and bending moment will be applied through a simulated service module section. LEM inertial loads will be applied through a fixture which simulates the LEM rigidity and LEM to adapter interface. Differential pressure environment existing at maximum qα will be applied. Loads and pressures will be applied simultaneously in approximately ten equal increments to limit magnitudes. Loading environment will be incrementally relieved to zero and a check will be made for yielding.

Test Condition III, Limit Level - End Boost First Stage. Inertia loads will be applied at the same locations as the condition II tests. No pressure environment will be simulated. Loading environment will be applied in approximately ten equal increments to limit magnitudes and incrementally relieved to zero. A check will be made for yielding.

Test Condition III, Ultimate Level - End Boost First Stage. Condition III limit tests will be repeated to ultimate level magnitudes.

Test Condition II, Ultimate Level - Maximum qα. Condition II limit tests will be repeated to ultimate level magnitudes.

12.3.4.3.1.6 Facilities and Equipment. The spacecraft LEM adapter static tests will be performed at the NAA Structural Test Laboratory at Tulsa, Oklahoma.

Strain, deflection, pressure, and load transducers with applicable recording equipment will be required for data acquisition, and monitoring application of loading environments.

[redacted]

The following special test fixtures will be required.

1. Simulated service module - Shear loads, axial loads, and bending moments will be applied to the adapter through a fixture fabricated such that spacecraft boundary conditions at the service module to adapter interface are simulated.

2. LEM loading fixture - Shear loads and axial loads will be applied to the adapter through a fixture fabricated such that spacecraft boundary conditions at the LEM to adapter interface are simulated.

3. Simulated S-IVB instrument unit - Loads applied to the adapter will be reacted through a fixture fabricated such that spacecraft boundary conditions at the instrument unit to adapter interface are simulated.

12.3.5 Combined Module Structural Tests

12.3.5.1 Complete Assembly Tests

12.3.5.1.1 Combined Module Static Tests - Command Module and Service Module (ATR 600).

12.3.5.1.1.1 Background Information. The tests performed under ATR 600 will evaluate the structural integrity of the command module and the service module structures for critical boost phase loading environments and for operation of the service propulsion system. This series of tests will be performed on combined modules to ensure spacecraft boundary conditions at the command module to service module interface and inter-modular components.

Boost phase loading environments are critical for most of the basic structure of the service module and portions of the command module structure. Critical combinations of aerodynamic and inertia loads and differential pressure exist at three time points during boost phase: lift off, maximum $q\alpha$, and end boost first stage. Operation of the service propulsion system in space induces critical loading of the engine mounts and backup structure.

The basic service module shell is critical for both the maximum $q\alpha$ and end boost conditions. The outer shell has low margins during the maximum $q\alpha$ condition at both the aft end due to body bending loads and the forward end due to RCS engine housing and tank loads. The critical areas are at the redistribution closeout at spacecraft station 841, the outer face sheets at the forward end directly off the doubler, and the radial beam outer flange in the RCS areas where large bending moments are transferred through adjacent panels.

[redacted]

The end boost condition has slightly lower body loads but the degradation of mechanical properties makes this condition the most critical. The critical areas are directly off the doublers at the spacecraft station at 845.

The venting of the spacecraft will be such that during the high aerodynamic pressure loadings the net or gage pressure across the shell wall is bursting. This precludes the instability situation for panel compression and external collapsing pressure. The pressure loading will create deflections of significance radially which allow a secondary bending or beam column stress. These high values occur in the central panel locations.

Stiffness evaluation tests will also be performed under ATR 600. These tests will determine deflections of combined modules under unit loads and bending moments, and also during mating.

12.3.5.1.1.2 Test Article. The test article will consist of spacecraft configuration command module and service module structures. No ablative covering or nonstructural systems will be installed.

Tests will be conducted with the service module mounted to a transition section approximately four feet in length. The transition section will be fabricated such that spacecraft boundary conditions at the service module to spacecraft LEM adapter are simulated.

The command module will be mated to the service module as a portion of the stiffness evaluation tests. Limit and ultimate magnitude loads tests will be conducted on this configuration (transition section, service module, and command module).

12.3.5.1.1.3 Test Objectives. The test series outlined below has been formulated to satisfy the following objectives.

1. To evaluate the structural integrity of the combined modular structure for critical boost phase flight environments of aerodynamic and inertia loads, and differential pressure.

2. To evaluate the structural integrity of the SPS engine mounts and supporting structure for critical conditions of SPS engine operation.

3. To verify analytical stress and loads analysis of combined modular structure for critical load environments.

[redacted]

4. To verify analytical rigidity analysis of combined modular structure in bending, torsion, and axial compression.

12.3.5.1.1.4 Test Conditions. Primary test objectives will be satisfied by subjecting the service module with the command module (or command module fixture as noted) to conditions of static load and pressure which simulate critical flight conditions - Saturn V boost.

Secondary objectives will be satisfied by determining load distribution in the service module beam trusses during mating with the command module, and also subjecting the combined modular stack to unit load/deflection tests.

Test Condition I - Stiffness Evaluation - Combined Modules. Condition I tests will determine load distribution in the service module radial beam trusses during mating with the command module. Load distribution will be measured for 1.0G command module reaction and for 1.0G plus tension tie effects. Applicable spacecraft procedures will be employed for mating operations.

After load distribution/mating tests, the combined modules will be subjected to unit torsion, bending moments, and unit static longitudinal compression load. Deflections of the service and command modules will be measured.

Test Condition II - Lift-Off. Condition II tests will evaluate the structural integrity of the command and service modules for critical lift-off condition loading environment, Saturn V launch.

Static test loads will be applied to the command module to induce specified shear load, axial load, and bending moment at the command module to service module interface. Structure in the interface area only will be evaluated for lift -off condition loading environment.

Test Condition III - Maximum $q\alpha$. Condition III tests will evaluate the structural integrity of the service module for critical max $q\alpha$ loading environment, Saturn V launch. Command module to service module interface loads will be simulated by static loading of the command module hard points. Inertial loads of major masses will be applied. Aerodynamic pressure distribution on the service module will be simulated.

Test Condition IV - End Boost First Stage. The service module will be subjected to static loads simulating the loading environment of end boost first stage, Saturn V launch. Test loads will be applied to simulate inertia

[redacted]

[redacted]

of all major masses. Service propulsion system fuel and oxidizer tank rigidity will be simulated. All applied test loads will be reacted at the transition section. No pressure or thermal environment will be simulated.

Test Condition V - SPS Engine Thrust Loads. The service module service propulsion system (SPS) engine mounts and supporting structure will be subjected to simulated thrust loading based on operation of the SPS engine in space. Tests will be performed on the spacecraft service module structure with SPS engine gimbal ring and pitch and yaw actuators.

Static loads will be applied in each of the three critical thrust vector orientations. An actuator force will also be applied at each orientation. Test loads will be applied to the gimbal ring through a rigid fixture used in previous stiffness evaluation tests.

12.3.5.1.1.5 Test Plan. The test will be performed in the following sequence:

1. Condition I (stiffness evaluation)
2. Condition II, limit level (lift-off)
3. Condition II, ultimate level (lift-off)
4. Condition III, limit level (maximum $q\alpha$)
5. Condition IV, limit level (end boost first stage)
6. Condition V, limit level (SPS engine thrust loads)
7. Condition V, ultimate level (SPS engine thrust loads)
8. Condition IV, ultimate level (end boost first stage)
9. Condition III, ultimate level (maximum $q\alpha$)

All tests will be performed with the test article installed in the vertical test facility.

Weights and centers-of-gravity of the test article and fixtures are to be determined and the magnitudes of applied loads adjusted accordingly.

Where practical, instrumentation for all test conditions will be installed prior to condition I tests.

[redacted]

Instrumentation data will be recorded at each stabilized load increment.

Simulated SPS propellant tank fixtures will be installed prior to command module mating.

Pretest static loads and pressures applied to checkout equipment will not exceed 40 percent of specified limit values for each test condition.

Test Condition I - Stiffness Evaluation. The stiffness evaluation tests will be performed in four phases. After phase 1 is completed, the sequence of performing phases 2, 3, and 4 is optional. The service module and transition section will be installed in the static test facility for command module mating. The transition section will be secured directly to the fixture.

Phase 1 - Command Module Mating. For the command module mating operation a fixture will be installed at the launch escape tower (LET) fittings of the command module to apply sufficient static load to simulate 1.0G spacecraft conditions. The LET fixture will be designed for use also in subsequent static loads tests.

Data will be recorded during mating of the command module to the service module to determine load distribution in the radial beam trusses from 1.0G reaction and also from 1.0G plus tension tie effects. Applicable spacecraft procedures will be followed during mating and a sufficient load will be applied to the command module launch escape tower fixture to simulate 1.0G spacecraft conditions. After data acquisition at the 1.0G condition, the tension ties will be engaged and torqued to the specified values. Instrumentation data measuring the combined effect of 1.0G spacecraft command module and interface tension ties will be recorded.

Phase 2 - EI Bending Constant. The EI bending constant test will be performed by incremental application of couple forces to the launch escape tower fixture. Couple forces will be applied in five equal increments to induce a uniform bending moment. Forces will be incrementally relieved to zero.

Phase 3 - GJ Torsion Constant. The GJ torsion constant test will be performed by incremental application of couple forces to the launch escape tower fixture. Couple forces will be applied in five equal increments to induce a uniform torsional moment, M_x. Forces will be incrementally relieved to zero.

[redacted]

Phase 4 - Axial Compression Constant. The axial compression test will be performed by incremental application of forces in the -X direction to the launch escape tower fixture. Force will be applied in five equal increments to induce a compressive force. Forces will be incrementally relieved to zero.

Test Condition II - Limit Level - Lift-Off. Lift-off condition tests will be performed by application of static loads to the launch escape tower fixture. Applied load magnitudes will be selected to simulate load environment at station $X_a = 1010$. Specified limit load will be applied in ten equal increments to the command module launch escape tower fixture. Loading will be relieved to zero and a check will be made for structural yielding.

Test Condition II - Ultimate Level - Lift-Off. Limit level tests will be repeated to ultimate level loads.

Test Condition III - Limit Level - Max $q\alpha$. Lateral inertial loads on internal masses are considered negligible and will not be simulated. Longitudinal inertial and drag loads will be applied to the service module at the following locations.

1. Command module to service module interface by static loading of the launch escape tower fixture and heat shield.

2. Each of four SPS propellant tank to aft bulkhead interfaces through fixtures simulating the SPS tanks.

3. SPS engine to spacecraft gimbal ring and actuators through SPS engine fixture.

4. Attachment points or interfaces of each of the two helium tanks, the two liquid oxygen tanks, the two liquid hydrogen tanks, the RCS tankage and engine housing, and the three fuel cells. Loads will be applied through spacecraft or simulated spacecraft connecting hardware.

The differential pressure distribution will be simulated. Pressure distribution will be applied in increments simultaneously with static loads.

Fixtures and set-up will be designed for continuing max $q\alpha$ condition tests to structural failure of the test article. (Command module will be replaced by a command module fixture for the failure test.) Specified limit loads will be applied to the command module launch escape tower

[redacted]

fixture, RCS engine housings, and internal load fixtures in ten equal increments. Simulated aerodynamic pressure environment will be applied simultaneously. Applied loads and pressure environment will be relieved to zero and a check will be made for yielding.

Test Condition IV - Limit Level - End Boost First Stage. The internal longitudinal inertial loading fixtures and command module launch escape tower fixture of condition III will be used for application of end boost first stage loads. Aerodynamic pressure simulation fixtures may be removed to facilitate performance of condition IV tests where necessary.

Specified limit level static loads will be applied in ten equal increments. Applied loads will be relieved to zero in five equal increments and a check will be made for yielding.

Test Condition V - Limit Level - SPS Engine Thrust Loads. Critical engine thrust and gimbal actuator loads will be applied simultaneously in approximately ten equal increments to design limit thrust and actuator loads. Applied loads will be relieved to zero in five equal increments. Longitudinal component of thrust load will be reacted by an equal and opposite load applied to the launch escape tower fixture.

Test Condition V - Ultimate Level - SPS Engine Thrust Loads. Limit level tests will be repeated to ultimate level loads.

Test Condition IV - Ultimate Level - End Boost First Stage. Limit level tests will be repeated to ultimate level loads.

Test Condition III - Ultimate Level - Max $q\alpha$. Limit level tests will be repeated to ultimate level loads.

12.3.5.1.1.6 Facilities and Equipment. The combined module static tests will be performed at the Space Science Development Facility of S&ID at Downey, California.

Strain, deflection, pressure, and load transducers with applicable recording equipment will be required for data acquisition, and monitoring application of loading environments.

The following special test fixtures will be required.

1. Transition section - The service module will be mounted to a fixture fabricated such that spacecraft boundary conditions at the service module to spacecraft LEM adapter interface are simulated.

[redacted]

2. SPS propellant tank fixtures - The two oxidizer and two fuel tanks of the SPS will be simulated. Interface configuration at the forward bulkhead and aft bulkhead, and stiffness in bending between the bulkheads are the simulation requirements. The simulated tanks will have provisions for applying longitudinal inertial loads to the spacecraft structure at the aft bulkhead.

3. SPS engine fixture - The inertial force of the SPS engine will be applied to the spacecraft gimbal ring and structure through a test fixture. No stiffness simulation is required, and the fixture shall be rigid. The fixture will have provisions for attachment to the spacecraft gimbal ring assembly and actuator, and for application of ultimate level thrust loads.

4. Tankage and fuel cell fixtures - Fixtures are required to apply inertial forces at the two liquid hydrogen tanks, the two liquid oxygen tanks, the two helium tanks, and the three fuel cells. Stiffness simulation is not required; however, tankage and fuel cell to spacecraft structure interface configuration is required. All fixtures will be capable of applying ultimate level longitudinal inertial loads. Lateral inertial forces will not be applied.

5. Launch escape tower fixture - Fixture is required to apply approximately 50% of the command module to service module interface test loads. Fixture configuration will permit installation at the command module launch escape tower fittings.

6. Command module heat shield fixture - Approximately half of the longitudinal loading applied to the command module for end boost first stage and maximum $q\alpha$ conditions will be applied to the command module heat shield. The fixture will be designed to apply a uniformly distributed loading in the station 1023 to 1081 area.

12.3.5.1.2 <u>Static Structural Cold Soak Test - Command Module and Service Module (ATR 611).</u>

12.3.5.1.2.1 Background Information. The tests to be performed under ATR 611 are designed to provide a full scale structural design evaluation of the spacecraft (command module with ablative heat shield and the service module) for simulated environmental conditions associated with earth orbit and subsequent lunar missions.

[redacted]

[redacted]

12.3.5.1.2.2 Test Article. A complete spacecraft configuration, which generally duplicates the flight spacecraft, will be used. The command module, complete with ablator, and a service module will be mounted on a special test stand in an environmental chamber capable of simulating earth orbit and lunar space conditions.

12.3.5.1.2.3 Test Objectives. Full scale structural design evaluation tests will be performed on the spacecraft configuration and the command module in particular under the cold soak environment to meet the following objectives

1. To verify the structural characteristics (i.e. stress and deflection) of the bi-material command module heat shield under the cold soak environment.

2. To verify the ability of the stringers, frames, and rings to allow the heat to contract without inducing excessive loads on the inner cabin structure, or between interfaces of the heat shield sections.

3. To verify the operation of mechanical devices (such as the astrosextant door) during and/or subsequent to exposure to environmental extremes.

12.3.5.1.2.4 Test Conditions. The tests under ATR 611 will be phased into the series of environmental proof tests planned for the same test article.

Condition 1 (First Manned Flight Requirements). The command module will be subjected to a cold soak environment until the heat shield substructure attains a steady state bondline temperature of -150 F. The cooling rate need not simulate the real-time-temperature history, but it is not to exceed a 100 F temperature differential across the heat shield composite.

The normal operating inner cabin temperature and pressure will be maintained for the test duration. The pressure differential between the inner cabin and the test chamber will be maintained at 5 psig. For this test, if chamber pressure is sea level ambient (14.7 psia), a 5 psig (19.7 psia) inner cabin pressure is satisfactory.

Condition II (Lunar Transit Mission Requirement). Same as phase I, except that the depressed steady state temperature will be -260 F.

Condition III (Random Drift-Lunar Space Orientation). Same as phase I, except that the command module will be subjected to a programmed thermal gradient such that the +Z axis meridian is at -250 F, whereas the -Z axis is at 250 F.

[redacted]

12.3.5.1.2.5 Test Plan. Tests will be performed in the following sequence.

1. Condition I, cold soak environment - first manned flight

2. Condition II, cold soak environment - lunar transit mission

3. Condition III, random drift - lunar space orientation

For the structural cold soak tests, the test article will be mounted on a spacecraft support base. Strain gage and thermocouple requirements are given in the Apollo Engineering Environment Test Requirements Report (ATI-TR-008). Deflection gages will be incorporated in this report at a later date.

For all tests, strain, deflection, and temperature gage measurements will be recorded every 10 F during cooling, at steady state temperature, and every 10 F during thawing period. Actual times required to cause a 10 F change during the cooling and thawing phase will be recorded.

After the heat shield reaches the specified test temperature, the mechanically operated astrosextant and telescope cover will be operated to demonstrate the capability to function satisfactorily when exposed to the cold soak environment.

Upon completion of each test, the test article will be visually examined at ambient conditions for evidence of failure. The test procedure for each condition was presented under the test conditions.

12.3.5.1.2.6 Facilities and Equipment. The structural cold soak tests will be performed at the MSC Space Environment Facility in conjunction with the system and subsystem developed test plan (test philosophy) as reflected in SID 62-223, Apollo Program Plan.

13.0 MECHANICAL AND ORDNANCE DEVICES*

13.1 SCOPE

The mechanical and ordnance devices test program encompasses all development and design testing required to verify the ability of the Apollo spacecraft mechanical and ordnance devices to withstand critical mission environments and loads. The primary program test areas include development and evaluation tests on components and complete units of the following:

Command module
Service module
Spacecraft adapter
Launch escape system
Earth landing system

The final design verification of separation devices will be performed in conjunction with structural tests as described in Section 12.0, Structural Tests.

13.2 INDIVIDUAL TESTS

13.2.1 Separation Subsystem—Separation of Command Module From Service Module

13.2.1.1 Objectives

The operational characteristics of a subsystem in its initial design configuration will be determined by testing under simulated environmental and critical loading conditions. Data obtained from the tests will be used to improve the subsystem by modification or redesign. In particular, the investigation will include the disconnect characteristics of the tension ties, electrical and environmental interface disconnects, and the operation of pyrotechnic release devices. The time required to effect complete intermodule release will also be determined.

13.2.1.2 Test Plan

Detail tests will be run on each of the separation points having the electrical and environmental interface disconnects. Separate cycles will be run under various environmental and loading conditions. Instrumentation

*Entire section reissued

will be employed to measure release time, phasing of electrical and environmental structural disconnects, and other functional parameters. Complete subsystem tests will be run to determine the characteristics of pyrotechnic separation devices, the phase characteristics, and the time required to effect complete intermodular release. Articles to be tested are boilerplate and prototype devices. Purchased items are included.

13.2.1.3 Equipment

A skeletal jig will be required. This jig will provide the attachment and a structural simulation of the actual rigidity of the command module and service module structural interface.

13.2.1.4 Facilities

S&ID facilities will be used.

13.2.2 <u>Separation Subsystem—Service Module From Adapter</u>

13.2.2.1 Objectives

The objective is to determine the operational characteristics of the subsystem in its initial design configuration by testing it under simulated environmental and loading conditions. Data obtained from these tests will be used to improve the subsystem by modifying or redesigning. In particular, the investigation will include the structural separation characteristics, initiation, and sequencing devices. The time required to effect complete intermodular release will be determined.

13.2.2.2 Test Plan

Detail tests will be run on structural samples that are identical to the honeycomb in every respect but panel size and on the electrical interface disconnect. Separation tests will be run under critical environmental and loading conditions. Approximately five full-scale models of the adapter will be used for system testing. Instrumentation will be employed to measure separation time, the phasing of electrical structural disconnect, and other functional parameters. Complete subsystem tests will be run to determine characteristics of initiation and sequencing devices and the time required to effect complete intermodular release. Articles to be tested are structural samples and prototype structure at the separation interface. Purchased items are included.

13.2.2.3 Equipment

A skeletal jig will be required. This will provide the attachment and support for prototype structure in the vicinity of the various locations where separations will occur.

13.2.2.4 Facilities

S&ID facilities will be used.

13.2.3 <u>Separation Subsystem—Escape Tower From Command Module</u>

13.2.3.1 Objectives

Design analysis of the release and separation of the escape tower from the command module is to be verified. Environmental and loading conditions will be simulated.

13.2.3.2 Test Plan

The ease with which the escape tower can be attached to the command module will be determined. The feasibility of access for connecting and disconnecting the umbilical electrical connector will be established. The adequacy of the clearance of tower legs with the command module at the critical separation angle will be verified. Separation tests will be conducted under actual load conditions to determine the time required for complete separation of the escape tower, as well as to evaluate the disengagement of the umbilical connectors.

13.2.3.3 Equipment

A skeletal jig of the lower portion of the escape tower and a structural simulation of the upper cone of the command module will be needed. These jigs must duplicate the prototype configuration with respect to accessibility, rigidity, and detail design where the escape tower and command module are attached.

13.2.3.4 Facilities

S&ID facilities will be used.

13.2.4 <u>Crew Couches and Shock Attenuation Subsystem</u>

[redacted]

13.2.4.1 Objectives

Data will be provided for evaluation and modification of the dynamic characteristics of the shock attenuation subsystem wherever necessary. The functional performance of couch adjustments, shock strut adjustments, lockout devices, etc., will be checked and evaluated. The structural integrity of the complete subsystem will be proved.

13.2.4.2 Test Plan

The instrumented and assembled prototype crew couches and shock strut attenuation subsystem will be installed in the drop test fixture. Weighted mannikins or other suitable mass simulators will be placed on the couches and restrained in the proper manner. Progressive drop tests will be made from various heights and at attitudes that will produce the critical loads. Data from these tests will be analyzed to evaluate the dynamic characteristics of the shock attenuation subsystem in all modes of operation. Tests will be performed to limit loads. The proper functioning of shock struts, adjustments, lockout devices, etc., will be checked. Structural requirements may make it necessary to continue tests to the point at which failure occurs. Static load tests will be performed on parts of the couches and on the shock attenuation subsystem. Deflection measurements from simulated steady-state g loadings will be made and compared with design values. Two complete crew couch assemblies and the shock strut attenuation subsystem will be tested.

13.2.4.3 Equipment

Drop test fixtures and related support equipment will be needed, as well as typical strain gauge and oscillograph recording equipment and high speed motion picture equipment, for use on the drop tests.

13.2.4.4 Facilities

S&ID facilities will be used.

13.2.5 Pressure Compartment Access Testing

13.2.5.1 Objectives

One aim of this testing is to define the most desirable of several reasonably convenient means of egress or ingress with respect to the command module. The means selected should result in a minimum loss of the environmental integrity of the command module under conditions of design mission (launch, long-term exposure to the space environment, entry, etc.).

[redacted]

A second aim is to determine the general design characteristics (unlocking forces, travels, etc.) of the preferred systems during exposure and after exposure to appropriate environmental conditions. A third aim is to verify the capability of the subsystems to maintain the desired environmental integrity throughout the conditions encountered during the missions.

13.2.5.2 Test Plan

Mechanisms will be cycled under appropriate environmental conditions, and forces, travels, etc., will be recorded. Test assemblies will be exposed to critical environmental conditions. Performance characteristics (leakage rates, etc.) will be recorded. Preferred subsystems will be determined and selected on the basis of performance. The subsystem will be cycled during and after exposure to all critical environmental conditions. The major characteristics (forces, travels, etc.) of hatches, as well as those of the latching and actuating mechanisms, will be recorded and compared to design requirements.

13.2.5.3 Equipment

Supporting structure and a sealed structure across the inside of the hatch will be needed to develop a pressure differential in a vacuum chamber. Fixtures will be required to support components and to simulate spacecraft subsystems. Vacuum chamber, radiant heating panels, standard laboratory equipment for measuring and recording leakage rates, forces, etc., will also be needed.

13.2.5.4 Facilities

S&ID facilities will be used.

13.2.6 Positioning Devices

13.2.6.1 Objectives

Testing will determine the characteristics of initial subsystem components of the astro-sextant door mechanisms. Assurance will be obtained that these components of the subsystem shall perform their functions satisfactorily when subjected to the appropriate environmental, loading, and cycling conditions.

13.2.6.2 Test Plan

The mechanisms will be cycled during and after exposure to extremes of environments and loads. A prototype chain and sprocket mechanism with recommended dry film lubricant will be cycled at load in a vacuum chamber at extreme environmental conditions expected on the mechanism during a flight. Four sets of rotary flexible drive shafts will be cycled a large number of times at various loading conditions to determine performance characteristics such as backlash, operating torque, static breakaway friction, efficiency, and endurance.

13.2.6.3 Equipment

Supporting structure simulating the actual structural rigidity in the region of the subsystem, as well as jigs, will be needed, as required, to mount support structure for the test systems. Standard laboratory equipment will be required for measuring forces, travels, deflections, etc. Means for simulating appropriate environmental conditions, such as a vacuum chamber, radiant heating panels, etc., will be supplied.

13.2.6.4 Facilities

S&ID facilities will be used.

13.2.7 Forward Compartment Cover (Heat Shield) Release Subsystem

13.2.7.1 Objectives

This test will develop the subsystem used to retain the forward compartment cover and eject it prior to main parachute deployment under all possible flight conditions.

13.2.7.2 Test Plan

The test jig will be installed in a suitable area and the several cover ejection methods operated. Measurements of force, acceleration, and trajectory recorded during these tests will complete the cover attachment and ejection subsystem test.

13.2.7.3 Equipment Required

A jig simulating the forward compartment, the forward bulkhead (station 82.75), the connecting tunnel, a heat shield and a simulated launch escape tower will be required. Fixtures will include a method for catching the heat shield without damage after ejection and to simulate airloads on the cover. Instrumentation for this test will include a high-speed motion picture camera synchronized with force and acceleration recording devices.

13.2.7.4 Facilities

S&ID facilities will be used.

13.2.8 DSIF Antenna Deployment Subsystem

13.2.8.1 Objectives

Determine the operational characteristics of the subsystem in its initial design configuration by test under simulated loading conditions. Data obtained from these tests will be applied to improvement of the subsystem by revision or redesign. These tests will determine if a damper is required to provide correct deceleration rates, what forces the deployment spring should apply, the amount of free play in the complete subsystem and if a device is necessary to reduce this free play. Also stiffness of the boom will be determined.

13.2.8.2 Test Plan

The deployment mechanism will be cycled a number of times using various input forces and recording of acceleration rates will be obtained throughout the cycles. The amount of free play throughout the mechanism will be recorded. Stiffness of the mechanism will also be measured. This mechanism will be revised if necessary and tests repeated with the revised mechanism to verify that the mechanism will perform satisfactorily.

13.2.8.3 Equipment

A support structure providing the attachment and pivot points of the subsystem mechanism will be required instrumentation for this test and will include force and acceleration recording devices.

13.2.8.4 Facilities

S&ID facilities will be used.

13.2.9 Astro-Sextant Door Mechanism Subsystem

13.2.9.1 Objectives

The objective of this test will be to test a complete astro-sextant door mechanism subsystem with simulated doors and structure to determine clearances, proper rigging procedures, and to verify that the complete subsystem forces are within acceptable limits. This setup will also provide an engineering tool to modify and improve the mechanism where needed.

13.2.9.2 Test Plan

During installation of the components of the subsystem, the simulated doors, and structure, any deviation from the rigging specification will be noted and the specification revised to incorporate required changes. Any problem areas that should be corrected to improve the design (such as smoother operation, larger clearances, case of installation and proper sequence of installation) should also be noted. Data on various sections of the mechanism will be obtained to verify that all forces are within acceptable limits. These data will be compared later with the actual subsystems installed on the spacecrafts.

13.2.9.3 Equipment

Standard laboratory equipment will be required for measuring forces, travels, deflections, etc.

13.2.9.4 Facilities

S&ID facilities will be used.

14.0 MATERIALS, PROCESSES, AND PRODUCIBILITY

14.1 SCOPE

This section is intended to describe the planned approach to Apollo materials, processes, and producibility. It is probably impossible to anticipate all of the materials and producibility problems to be solved during the course of Apollo design and manufacturing. It is estimated that the tests and investigations will constitute only 35 to 50 percent of those that must ultimately be resolved.

The major criteria for design and material selection in the early spacecraft prototypes will be their successful airborne history. The materials research and process development work in support of this project will thus seek improvements and will be phased in at manufacturing or design change points after the process or material has been evaluated for producibility, reproducibility, and reliability under simulated prelaunch and space environmental conditions. The final proof of any material or process developed in support of this project will be its successful use on an unmanned spacecraft, prior to its firm incorporation into the design of a spacecraft intended for a manned mission.

14.2 S&ID TEST PLANS

14.2.1 Command Module Structure and Subsystem Installation

This constitutes a major portion of the Apollo materials and producibility effort. The command module structure and subsystems installation covers work on the structure, observation windows, the outer structural shell, the charring ablator, the inner structural shell, and the many items related thereto:

14.2.1.1 Objectives

The basic or primary objectives of the command module structure and subsystem installation are generally encompassed by the following:

1. Investigation of candidate materials properties from which the command module can be designed and fabricated. These materials are to be from commercially available stock, whenever possible

[redacted]

2. Selection of construction materials for the command module structure which meet functional requirements and established weight requirements or goals and which are capable of reliable function in the combined induced and natural hyperenvironments of space as encountered on a lunar mission

3. Testing and development of materials combinations, as required, when they are not available commercially, to achieve the most nearly optimum combination of reliability, economy, and producibility

4. Select and/or develop design criteria and fabrication methods which are required to produce a reliable subsystem capable of fulfilling all Apollo requirements within the required time period established by NASA

5. Define requirements of all materials required in the command module structure

14.2.1.2 Test Plan

The highlights of the test plan are presented in the following outline:

1. Conduct studies and necessary tests of applicable materials to determine properties, flammability and outgassing of toxic materials, and select candidate materials for each item required

2. Conduct additional tests, as required to establish mechanical and physical properties of candidate materials

3. Investigate the following items with respect to the inner shell of the command module:

    Candidate aluminum alloys

    Forming methods for materials

    Evaluate various methods and materials required to produce bonded aluminum honeycomb-type sandwich structural elements

    Determine the environments to which the inner command module shell materials will be subjected

    Subject specimens to simulated combined environmental conditions; if they are satisfactory, specify them; if they are unsatisfactory, continue developmental efforts until satisfactory results are achieved

4. Investigate requirements for openings in the inner shell and develop satisfactory methods for sealing provisions, etc., for these openings

5. Investigate, conduct necessary tests, and develop reliable methods for providing adequate lubrication for mechanical moving mechanisms (or movable mechanisms which are required as part of the command module)

6. Investigate, develop, and test, then specify as necessary, finishes for the command module inner shell and its components, including those required for a 100-percent oxygen atmosphere

7. Develop data and conduct necessary tests to describe optimum observation window materials, dimensions, processing, and coatings required for antireflectance and absorption of undesirable portions of the light spectrum, such as infrared and ultraviolet. Observation window materials must maintain an acceptable transmission level for the visible portion of the spectrum.

8. Conduct studies and evaluations as required to select materials from which the outer command module structural shell will be made. These include complete evaluations of such materials as aluminum alloys, titanium alloys, alloy steels, nickel base alloys, and cobalt base alloys

9. Conduct studies, evaluations, and tests to determine the best method to be utilized in fabricating outer command module structural shell honeycomb type sandwich components. These methods include adhesive bonding, diffusion bonding, welding (as with stresskin), and high temperature brazing

10. Conduct cryogenic, room, and elevated temperature tests to determine the important mechanical properties of such structural honeycomb type sandwiches as:

    Adhesive bonded aluminum alloy

    Diffusion bonded sandwich with 6Al-4V titanium alloy faces and commercially pure titanium core

    High temperature brazed 14-8Mo sandwich

    Rene 41 high temperature brazed, nortobrazed, and stresskin

[redacted]

HS-25 cobalt base brazed superalloy sandwich

HS-25 cobalt base superalloy stresskin (all-welded sandwich)

11. Determine the cryogenic and elevated temperature properties of elastomeric materials required for command module fabrication

12. Determine the most reliable methods for attachment of the charring ablative material to the outer structural shell of the command module

13. Conduct tests and employ experimental methods required to form and fabricate command module components. These include mechanical fastening, welding, bonding with adhesives, brazing, soldering, diffusion bonding, etc. Select and specify the optimum method to be employed in each fabrication step or assembly sequence

14. Conduct tests required to determine the ability of command module materials assemblies and/or elements to withstand the total combined natural and induced environmental combinations.

14.2.1.3 Equipment

The equipment required to perform all of the tests required for the command module structure and subsystem installation project exists only partially. The majority of the basic equipment required exists within the NAA corporate organization and combined outside organizations. Relatively little new equipment will be mandatory, although considerable modification of existing equipment is anticipated. Also, existing equipment must be made available, when needed, if new equipment procurement is to be avoided.

14.2.1.4 Facilities

No new facilities will be required for the material and producibility portion of the command module structure and subsystem installation. It is expected that currently available facilities, both within and outside the company, are adequate to cover this project.

14.2.1.5 Test Schedule

The command module structure and subsystem installation covers a sufficiently wide variety of different task types that a specific schedule cannot be applied to it. Work on this was initiated almost as soon as the project Apollo was started and will probably continue until the project is terminated. Work on material, process, and producibility improvement will probably closely follow completion of work on the basic spacecraft.

14.2.2 Service Module Structure and Subsystem Installation

The materials and producibility group effort on the service module structure and subsystem installation consists of the selection of materials, establishment of acceptable manufacturing and processing techniques, and determination of design properties of the materials used.

14.2.2.1 Objectives

1. Evaluate materials for the service module structure and substructure. These should be from commercially available materials, where possible

2. Select materials which meet the design requirements of the functional requirements and are compatible with load requirements

3. Compare the materials and manufacturing techniques from the standpoint of cost, producibility, and reliability

14.2.2.2 Test Plan

1. Conduct a study of the service module structure and determine the most suited materials for the applications in the service module

2. Determine the mechanical properties, physical properties, availability, and producibility of the selected materials for each application

3. Determine the environments that each material will be subjected to during the lunar mission and perform tests to insure satisfactory functioning during the mission

14.2.2.3 Equipment

The equipment necessary for this program is available in S&ID and other NAA divisions. No new equipment should be necessary for this testing and evaluation.

14.2.2.4 Facilities

No new facilities will be required for this program. All necessary facilities are available within NAA.

14.2.2.5 Test Schedule

The service module structure and subsystem installation effort will continue until the end of the program. A continual evaluation for improvement will be required as changes and manufacturing progress occur; therefore, no definite test schedule can be established.

14.2.3 Service Module Propulsion Subsystem

The materials and producibility group is testing materials and evaluating manufacturing and processing techniques for the fuel and oxidizer tanks and the associated plumbing system.

14.2.3.1 Objectives

1. Evaluate materials for the fuel and oxidizer tanks and select the material best suited for mission accomplishment
2. Select manufacturing and processing techniques for providing the most reliable system
3. Evaluate materials and brazing processes for the plumbing system associated with the fuel and oxidizer system and establish the best materials, fabrication, and processing procedures for the system
4. Determine the relative producibility and cost criteria and reliability of the fuel, oxidizer, and associated plumbing system
5. Demonstrate compatibility between the system components and their contents

14.2.3.2 Test Plan

1. Determine the mechanical properties of the materials selected for the fuel and oxidizer tanks in the environments to be experienced during the lunar mission (i.e., temperature, oxidizer, fuel, etc.)
2. Determine the manufacturing and processing methods which produce the most reliable system under the environmental conditions
3. Conduct tests to determine the tubing materials and manufacturing processes best suited for the plumbing system
4. Compare the cost, difficulty of production, and reliability to determine the optimum materials and manufacturing methods for the system

14.2.3.3 Equipment

The equipment necessary for the testing and evaluation of the materials and processes for this program is existent at S&ID and NAA Divisional facilities.

14.2.3.4 Facilities

No new facilities will be required to test the materials or evaluate the manufacturing processes. All facilities necessary are available within NAA or outside the company.

14.2.3.5 Test Schedule

Work on this system is expected to continue until the program is practically completed. Continuous design changes and manufacturing difficulties which will occur in the Apollo program will necessitate constant effort and surveillance on this part of the program.

14.2.4 Reaction Control System

The role of Apollo materials and producibility in the reaction control system is the selection and evaluation of materials in the environment to which the system will be exposed. Both the base material and the protective coating will be evaluated.

14.2.4.1 Objectives

1. Evaluation of the physical and mechanical properties of the selected rocket nozzle materials and comparison with other possible applicable materials

2. Evaluation of the properties of the nozzle coating and comparison with possible alternate materials

3. Testing of the nozzle material and coatings in the simulator hyper-environment of space (i. e., temperature, meteoroids, etc.)

4. Select or develop alternate materials in the event of failure of the selected materials to meet the specified requirements

5. Establish the packaging and handling methods and procedures for the RCS nozzles

[redacted]

14.2.4.2 Test Plan

1. Determine the properties of the material presently selected for the nozzle. Compare this data with existent data on other possible materials

2. Determine the properties of the nozzle coating presently selected and compare this data with alternate possible candidates

3. Determine the functionality of the nozzle and the coating in the mission environment

4. Develop packaging and handling procedures for the nozzles to prevent damage during handling and shipping

14.2.4.3 Equipment

The equipment necessary for the testing and evaluation of the nozzle materials and coatings is available within North American Aviation. No new equipment will be necessary for this evaluation.

14.2.4.4 Facilities

The facilities at S&ID and NAA Divisional facilities are adequate to handle this testing program.

14.2.4.5 Test Schedule

The work in this portion of the program is scheduled to be completed by June 1964.

14.2.5 Launch Escape Subsystem

14.2.5.1 Objectives

The launch escape subsystem includes both subcontracted and contractor fabricated elements. Such subcontracted items as the solid propellant launch escape rocket are not considered in this portion of the test plan. Basically, this section covers the launch escape tower and S&ID-fabricated accessories. Because the launch escape tower is to be ejected or jettisoned in the early part of an Apollo mission, materials utilized in its construction must exhibit the highest degree of efficiency from the standpoint of weight versus strength. Since the entire launch escape system must be lifted from earth by the first-stage rockets, substantial advantage is to be gained from the use of highly efficient structural materials. The firing of the launch

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escape rocket, either to separate the tower from the remainder of the system or to effect an escape, will result in sudden and severe heating of the structure. This will require protection for the structure. The general material and producibility objectives to be considered in connection with the launch escape subsystem are as follows:

1. Determine mechanical and physical properties of candidate materials from which the launch escape tower may be fabricated

2. Compare the properties of candidate materials and select those which are most nearly compatible with over-all requirements

3. Determine the relative producibility and cost criteria for candidate launch escape tower materials

4. Select the material combinations which most nearly fulfills all requirements for the Apollo spacecraft launch escape tower structure

5. Select the fabrication methods which appear most readily adaptable to launch escape tower fabrication

14.2.5.2 Test Plan

General elements of the launch escape subsystem test plan include, but are not necessarily limited to, the following items:

1. Obtain candidate launch escape tower materials and conduct mechanical and physical property tests to determine whether or not these materials are capable of meeting established requirements

2. Conduct necessary fabrication tests and evaluations to determine whether or not candidate materials can be readily converted from mill products into tubular products from which components can be readily fabricated

3. Investigate joining methods to be utilized in fabricating the launch escape tower and select such optimum methods of fabrication as TIG and MIG welding, electron beam welding, etc.

4. Determine the environmental conditions, such as temperature and vibration, which must be successfully withstood by launch escape subsystem components

5. Determine and apply methods of protecting launch escape subsystem structural components from the adverse effects of environmental extremes. Conduct tests required to demonstrate adequacy of such protective measures as thermal protective coatings, etc.

6. Demonstrate the ability of S&ID-fabricated launch escape subsystem components, by testing under simulated service conditions, to successfully withstand the total anticipated service environments and loads

14.2.5.3 Equipment

The equipment required for testing and evaluating the S&ID-fabricated portion of the launch escape subsystem is available either at S&ID or at other divisions of North American Aviation, Inc.

14.2.5.4 Facilities

Facilities for fabrication and testing of the S&ID-fabricated portion of the launch escape subsystem currently exist within the North American Aviation organization.

14.2.5.5 Test Schedule

Launch escape component and subsystem testing are scheduled for completion not later than 30 June 1964. Launch escape tower fabrication technique tests were completed on 21 December 1962.

14.2.6 Alternate Heat Shield

The purpose of this program is to select an alternate material for the heat shield material presently selected. The function of the materials and producibility group in this program is to evaluate the candidate materials and select one as the backup material.

14.2.6.1 Objectives

1. Evaluation of the physical, mechanical, and thermal properties of the candidate materials

2. Compare the properties of the various candidates and select the most likely materials, based on mission requirements for extensive testing

3. Test extensively the materials selected in Part (b) and compare the test data on these materials

4. Subject the candidate materials to the simulated space environment (i.e., ultraviolet radiation, particulate radiation, hard vacuum, etc.)

5. Select the material most suited as a backup material on the basis of properties and ability to withstand the environmental conditions

14.2.6.2 Test Plan

Phase I - Screening tests

1. Select candidate materials and prepare specification for each material

2. Fabricate the material and prepare test specimens for preliminary testing

3. Perform preliminary tests on mechanical and physical properties for screening the original materials selected

4. Perform preliminary environmental testing to screen the candidate materials

5. Select the most likely material from the original candidates for extensive testing

Phase II - Test program

1. Perform complete evaluation of the physical, mechanical, and thermodynamic properties of the candidate material selected in Phase I

2. Perform an evaluation of the behavior of the candidate material selected in Phase I in a simulated environment encountered on the lunar mission

3. Compile design allowables for Apollo space radiator and cold plate design on the back-up materials from the testing performed in Phase II

14.2.6.3 Equipment

The equipment necessary for the property testing of the candidate materials is available at NAA, S&ID and Divisional facilities. Some equipment may be necessary for the environmental evaluation of the candidate materials in Phase II.

14.2.6.4 Facilities

The facilities to be utilized in this program will include:

1. S&ID facilities
2. NAA Divisional facilities
3. Subcontractor facilities

14.2.6.5 Test Schedule

This program was completed in June 1963.

14.2.7 <u>Environmental Control Subsystem</u>

14.2.7.1 Objectives

The portion of the environmental control subsystem with which Apollo materials and producibility is concerned includes development of satisfactory fabrication techniques for space radiators and cold plates, selection and testing of temperature control coatings of the space radiator surfaces, and protection of these coatings from the time that they are applied to vehicle launch. The objectives of this task includes the following:

1. Selection of the most nearly optimum materials from which space radiators and cold plates are to be fabricated

2. Development of fabrication techniques for space radiator and cold plate fabrication

3. Determination of optical and physical requirements for temperature control surface coatings

4. Development and testing of temperature control coatings which fulfill basic system requirements

5. Determination of space environmental effects on space radiators and on temperature control surface coatings

14.2.7.2 Test Plan

The test plan includes the following specific items:

1. Based upon established system requirements, select the best available materials from which space radiators may be fabricated. Conduct tests, as necessary, to substantiate materials selection

2. Conduct necessary tests and experiments to determine optimum fabrication methods for space radiators. Conduct experiments required to prove that components fabricated by the method selected are capable of satisfactory operation in the space environment

3. Conduct screening tests to determine which of the available candidate temperature control surface coatings are capable of meeting minimum established optical and physical property requirements

4. Select candidate temperature control surface coatings meeting minimum requirements for additional tests

5. Subject candidate temperature control surface coatings to combined simulated service conditions, including ultraviolet temperature extremes, meteoroids, charged particle radiation, hard vacuum, etc., and select the coating(s) which best withstand simulated service environments

6. Modify and/or develop coating(s) as necessary to render them less vulnerable to environmental effects

7. Select the coating to be employed on the space vehicle and develop methods of protecting the temperature control surface from the time of coating deposition to the time of vehicle launch

14.2.7.3 Equipment

The equipment for work required in developing this portion of the temperature control system exists either at S&ID and other North American Aviation Divisions or at subcontractor facilities. It is expected that equipment modification may be required to permit application of temperature control coatings to relatively large panels required for the Apollo project.

14.2.7.4 Facilities

Existing S&ID and NAA divisional facilities are considered adequate for work required in this portion of the environmental control subsystem.

14.2.7.5 Test Schedule

All work included in this portion of the environmental control subsystem is scheduled for completion by 1 March 1965.

14.2.8 Communications Subsystem

The portion of the communications subsystem covered in this section of the test plan involves primarily evaluation of radome (telecommunication window) materials and miscellaneous items, such as cables, shielded wires, and connectors requiring materials evaluations.

14.2.8.1 Objectives

The objectives of this program involve the following:

1. Evaluation and studies of candidate materials and selection of those which should be seriously considered for Apollo communication subsystem application
2. Testing of candidate materials to determine whether or not they are capable of functioning satisfactorily under anticipated service conditions
3. Recommending communication subsystem materials for specific design applications on the Apollo vehicle after having determined environmental conditions under which related components must operate

14.2.8.2 Test Plan

The test plan for this portion of the communications subsystem is presented in the following items:

1. Determine the physical and mechanical properties of candidate materials which are considered in fabrication of:

   The discone antenna window (radome)

   Other radomes mounted on the command module exterior

   Cables, insulation, and various connectors which are utilized in both the command module exterior and interior

2. Conduct tests required to determine compatibility of candidate communication subsystem materials with a 100 percent oxygen environment

3. Conduct tests required to determine the single and combined effects of the space environment (charged particle radiation, hard vacuum, meteoroids, etc.) on specific candidate materials

4. Conduct the tests required to determine flammability of materials in a 100 percent oxygen atmosphere and tests to determine whether or not candidate materials emit undesirable fumes or gases

5. Conduct tests to provide mechanical property data on candidate ceramics (quartz, fused silica, alumina, beryllia, zirconia, etc.) for use as radome structures. Determine effects of simulated combined space environments on such materials

6. Determine electrical properties, as necessary, on candidate dielectrics

14.2.8.3 Equipment

The equipment required to evaluate and/or test communications subsystem materials is available at S&ID, at other NAA divisions, or at supplier facilities. No new equipment will be required for general materials testing.

14.2.8.4 Facilities

Facilities required for communication subsystem materials evaluation are considered to exist at one or more of the following facilities:

1. S&ID Laboratories
2. Other NAA Divisions
3. Material supplier facilities
4. Subcontractor facilities
5. Research and development organization facilities

14.2.8.5 Test Schedule

All testing of materials for prototype articles, as well as for production spacecraft items, are scheduled for completion not later than 1 March 1965.

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14.2.9 Radiation Testing of Materials

14.2.9.1 Objectives

Certain materials employed in the fabrication of the Apollo spacecraft may be, according to current literature, adversely affected by the amounts of charged particle radiation to which they can be exposed during a normal Apollo mission. In other words, their threshold damage may be exceeded on an average Apollo mission. The objectives of this program include the following:

1. Identify the charged particle radiation environment
2. Determine the threshold damage or damage limits for the material being investigated
3. Determine which materials will have their threshold damage limits exceeded on an Apollo mission and by what extent these limits will be exceeded
4. All materials that have threshold damage limits that may be exceeded on an Apollo mission will be subjected to simulated radiation environments (energies and quantities) which they will experience on an Apollo lunar mission. The damage caused by charged particle radiation during a mission will be determined
5. Pre-irradiation and post-irradiation tests will be required to show how much and what type of radiation damage has been sustained by each susceptible material
6. Based upon test results, a recommendation will be made either recommending use of or discontinuing use of each material susceptible to radiation damage.

14.2.9.2 Test Plan

The test plan consists essentially of the following items:

Basic Tests

1. Radiation screening tests on candidate alternate heat shield charring ablators.

2. Simulated charged particle space radiation doses to 31-mev protons of the following doses: 10^{11}, 10^{12}, 10^{13}, and 10^{14} protons per square centimeter.

3. Conduct pre-irradiation and post-irradiation tests necessary to determine the amount and type of radiation-induced damage caused by charged particle radiation exposures.

Long Range Tests

1. Long range tests may involve Teflon, Buna N rubber, silicone rubber, butyl rubber, ethylene glycol, aluminosilicate glass (observation window material), fused silica (heat shield window material), temperature control surface coatings, and other critical materials that may be susceptible to charged particle radiation damage.

2. Each material will be exposed to the charged particle radiation level (as nearly as possible) which it is likely to sustain on an Apollo mission. The types of radiation to which a typical surface material is likely to be exposed on an Apollo mission include gammas, 2 to 10-mev electrons, and protons of the following energies: 30 mev, 50 mev, 70 mev, 100 mev, and 160 mev.

3. All radiation exposures will be made while the specimens are in a 10^{-6} mm Hg vacuum or better.

4. Pre-irradiation and post-irradiation testing of specimens will be conducted before and after charged particle radiation exposures to determine if damage is caused by charged particle radiation.

5. Each series of materials tests and test results will be examined analytically to determine potential charged particle radiation effects on the over-all Apollo materials behavior.

6. Analytical work will also be conducted in an attempt to develop a method for accurately predicting space-type charged particle radiation effects on materials, based upon test data developed in reactor or similar type tests.

14.2.9.3 Equipment

The equipment required includes the following:

1. Scattering chamber assembly for holding test specimens in a combined vacuum at controlled temperatures during exposure to the charged particle beam

2. Miscellaneous minor optical measuring equipment for determining damage to temperature control coatings caused by charged particle radiation

3. Miscellaneous chemical-type equipment required for handling fluid materials while they are being irradiated

4. Beam time on electron and/or proton accelerators for exposure of specimens. This includes only beam time or use of charged particle accelerating equipment, not equipment purchase.

14.2.9.4 Facilities

No new facilities are needed. The use of existing accelerator site facilities will suffice. Existing NAA facilities will be adequate for anticipated preirradiation and postirradiation tests.

14.2.9.5 Test Schedule

Basic tests were completed in June 1963.

Long range tests are expected to require approximately one year from initiation of testing, provided that accelerator beam time can be obtained as easily as now appears possible. All charged particle radiation tests should be complete by 30 December 1964.

14.2.10 <u>Structural Leak Detection</u>

14.2.10.1 Objectives:

The maximum total leak rate for the Apollo cabin has been established as 0.2 pounds of oxygen per hour at differential pressure (this is equal to 1.8×10^{-1} cc of oxygen per second). To achieve this maximum leak rate, the following program objectives have been set:

1. Identify the welded joints where leakage can occur

2. Identify the rubber or elastomer sealed joints that may be subject to leakage

3. Determine practical leak detection methods that are sufficiently accurate to measure the total leakage taking place in a given area

4. Determine a practical method for measuring the total Apollo command module leakage, both prior to and subsequent to final assembly

5. Determine practical and accurate methods for checking handling damage, post-weld cracking, and weld repairs with respect to leakage

6. Prepare a process specification covering all significant facets of cabin leakage criteria.

14.2.10.2 Test Plan:

The following constitute the basic test plan for structural leak detection:

1. Investigate such methods as a vacuum cup using water and helium mass spectrometer methods for measuring leakage in weld areas and in rubber sealed areas, such as doors and windows

2. Select optimum methods for measuring the leakage rate at each type of site where leakage is likely to be encountered

3. Measure weld leakage prior to final assembly, using the optimum methods developed

4. Measure leakage caused by handling damage and post-weld cracking (if any), and check repaired areas for leaks

5. Measure leakage at the proper predetermined assembly events, such as the command module half-shell face sheets both before and after assembly into major subassemblies and final assembly.

14.2.10.3 Equipment

The equipment needed for all phases of this task has not yet been completely catalogued, but the following is a listing of the basic equipment that will be required:

1. A helium mass spectrometer with modifications

2. Bubble check range equipment, including a vacuum cup using water

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3. Specially designed and constructed or modified equipment based upon items 1 and 2 as required to permit checking of structural components that are peculiar to the Apollo command module.

14.2.10.4 Facilities

The requirement for new facilities is not anticipated. Existing NAA corporate facilities are now considered adequate for this task.

14.2.10.5 Test Schedule

This program encompasses a large number of different tasks, preventing application of effective scheduling. Development of leak detection and measurement techniques may be completed as soon as August 1964, but leak detection and measurement will continue throughout the entire spacecraft production period.

14.2.11 <u>Apollo Contamination Control</u>

Apollo systems, including fuel systems, coolant systems, etc., will be assembled from both NAA and subcontractor produced components. Maintaining an adequate level of cleanliness within these systems components as well as within the total assembled systems is absolutely imperative. This program is of utmost importance to successful spacecraft missions.

14.2.11.1 Objectives

The objectives of the contamination control program are as follows:

1. Establish cleanliness requirements that will be mandatory for the reliable function of each system

2. Provide materials, process, and producibility criteria to ensure that cleanliness requirements for the hardware are met and maintained, as well as being specified on applicable drawings

3. Determine specific system tolerance to particulate matter size and contamination level

4. Originate practical test methods for determining whether or not cleanliness requirements have been met by NAA and the subcontractors on the component, subassembly, and completely assembled systems levels

5. Investigate post-assembly contamination sources or causes, such as corrosion, vibration, micro-organisms, etc., and originate methods for salvage of contaminated components and/or systems

6. Educate suppliers, subcontractors, and NAA personnel to maintain adequate cleanliness standards during fabrication so that produced systems are free from objectionable contaminants.

14.2.11.2 Test Plan

The following constitute the basic test plan for the control of contamination:

1. Conduct investigations and tests of applicable system components required to establish cleanliness requirements

2. Prepare applicable specifications in which both general and specific cleanliness requirements are clearly stated

3. Conduct investigations required to determine sources of contamination and/or contaminants that cannot be tolerated. This includes investigation of fittings, filters, construction materials, and compatibility between systems and their intended contents

4. Investigate, study, and specify methods or means for eliminating contamination of systems and/or systems components, plus establish clean room requirements for component manufacture and system assembly

5. Determine the tests that will be conducted to ascertain if cleanliness requirements are met. Specify the events at which cleanliness tests are to be conducted. Conduct the tests as specified.

6. Determine the methods by which system components that have failed to meet cleanliness requirements can be salvaged. These methods may include flushing with solvents, ultrasonic cleaning, a combinations of these, etc.

7. Determine and specify methods for maintaining cleanliness of the components once they are determined to be clean. This includes component and subsystem storage, and post system installation cleanliness.

14.2.11.3 Equipment

The equipment necessary for this program is available within S&ID, other NAA divisions, or at outside facilities. Very little, if any, new equipment should be required for this program. Some equipment modification may be required.

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14.2.11.4 Facilities

No new facilities are foreseen as a requirement for this program. All necessary facilities appear to be available either within NAA or at subcontractor facilities.

14.2.11.5 Test Schedule

This program is expected to be continuous throughout the Apollo project. At this time, no test schedule can be established with any degree of accuracy.

15.0 WIND TUNNEL TEST PROGRAM

15.1 SCOPE

The scheduled wind tunnel test program will supply data on aerodynamic and rocket heating; stability during abort, entry and recovery; effects of center-of-gravity offset and heat shield ablation; interaction between separating bodies during escape operations; aerodynamic loads throughout the flight regime; and other problems that must be solved for the successful design of the Apollo.

A highly concentrated wind tunnel program is required to meet the internal release dates. This program will provide the necessary experimental data for the evaluation of the design and, wherever possible, will use large models for testing at Reynolds numbers approaching flight conditions. Detail design data will be generated, and detail design problems will be investigated, including tests of the Apollo recovery system and tests to assure compatibility between the command module and the other booster components.

15.2 TEST OBJECTIVES

The basic test objectives of the wind tunnel program are to provide, in the shortest possible time, sufficiently accurate and inclusive data to evaluate factors that affect the final design of the spacecraft, and to provide information to prove the validity of the configuration selected for final development.

15.2.1 Static Force Tests

Much of the initial testing to determine basic static stability and force characteristics of the entry and launch escape configuration throughout the flight regimes has been completed, using the FS-1, FS-2, FS-3, FS-4, and FS-8 models (For model definitions, see Section 15.4).

During transonic and supersonic tests of the FS-2 model, the individual loads acting on the escape motor and command module components of the launch escape vehicle were measured.

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Tests have been conducted in the subsonic, transonic, and supersonic Mach number ranges on the FS-1, FS-2, and FS-3 models to investigate various devices on the command module to eliminate the apex-forward trim point.

Tests to determine the stability characteristics for any further modification to the command module or launch escape vehicle will be conducted on the FS-2 and FS-3 models.

Static stability characteristics of the launch escape vehicle with the escape motor operating have been determined using the FSJ-1 model with hydrogen peroxide as a propellant, and the FSJ-3 model with unheated air as the propellant.

The static stability and force characteristics of the Saturn 1 with detachable stages and the Apollo payload have been determined over the Mach number range from 0.7 to 8.0 with the FSL-1 model. This model has furnished aerodynamic data for launch vehicle abort trajectory studies.

Free-flight characteristics of the command module and launch escape vehicle, including static and dynamic stability data, are being investigated in ballistic range facilities.

Tests of the drogue chute models FSC-1 and FDC-1 have yielded drogue inflation and stability characteristics and drag data. Various parachute diameters and porosities have been tested to verify the configuration selected for the recovery system.

15.2.2 Dynamic Force Tests

Dynamic stability characteristics of the command module and launch escape vehicle have been obtained in limited Mach number and angle-of-attack ranges using the FD-1 and FD-2 models. Additional tests of FD-2 obtained the dynamic stability characteristics for modifications of the launch escape vehicle configuration. Dynamic stability data have been obtained on the command module at angles of attack from -10 to +190 degrees in the Mach number range from 1.5 to 10 and on the launch escape vehicle at angles of attack from -5 to +25 degrees in the Mach number range from 1.5 to 6.0 using the FD-3 model. Subsonic dynamic stability characteristics of the command module and launch escape vehicle have been obtained using the FD-4 model.

High-amplitude free oscillation tests have been conducted for the entry configuration (FD-5 model) at angles of attack corresponding to the heat shield and apex forward trim points in the Mach number range of 0.6 to 6.0.

Using the same model, data were obtained for the launch escape vehicle at its trim angle of attack over a Mach number range 0.6 to 4.0. Tests to obtain the tumbling dynamic stability characteristics of the command module were run with various stabilizing devices at a Mach number of 0.2, using the FD-8 model. Additional tumbling dynamic stability tests of the command module and launch tower vehicle were conducted during December 1963 and January 1964, using the FD-6 model. The test Mach number range was 0.3 to 0.9.

Dynamic stability characteristics of the command module with the drogue chute have been obtained using the FDC-1 model. Parachute deployment characteristics with the command module at normal and apex forward trim also have been investigated.

15.2.3 Structural Dynamic Tests

The SD-1 model tests investigated the structural response of the Saturn-Apollo 1 launch configuration to buffeting loads in the transonic flight range. Measurements of aerodynamic damping have also been obtained from these tests.

15.2.4 Static Pressure Tests

Initial structural design loads were obtained for the command module and the launch escape vehicle from pressure measurements made on the PS-1 model in the Mach number range from 1.5 to 9.0. These data have been augmented with more complete pressure measurements on the PS-3 model in the Mach number range from 0.4 to 10. Pressure measurements have been obtained on the command module at Mach number 19.5 using the PS-4 model.

Tests have been conducted to obtain additional data on pressure loads for the launch escape vehicle with jet effects in the transonic range using the FSJ-1 model and in the supersonic range using the FSJ-3 model.

Pressure data with real gas effects have been obtained with the PS-5 model in the Mach number 15 region.

15.2.5 Static and Transient Pressure Tests

Static and transient pressure measurements have been made on the Apollo-Saturn 1 launch configuration in the Mach number range from 0.7 to 3.5 using the PSTL-1 model (Reported in SID 63-1480).

Static and transient pressure measurements have been made on the Apollo-Saturn 1B configuration in the Mach number range from 0-5 to 2.5 using the PSTL-2 Model.

15.2.6 Heat Transfer Tests

Initial heat transfer distributions were obtained for the command module and the launch escape vehicle from heat transfer measurements made on the H-1 model at Mach numbers 6, 7.3, and 9 in the JPL 21-inch hypersonic tunnel. These data have been augmented with more complete heat transfer measurements made on the H-2 model at Mach numbers 8 and 10, with higher Reynolds number simulation in tunnels B and C of the Von Karman Facility (VKF) at the Arnold Engineering Development Center (AEDC). Data have also been obtained at Mach 10 in the VKF tunnel C on the HL-1 and HL-1B launch configurations which incorporated the forward portion of the S-IVB stage. Mach 19 heat transfer data were obtained over the command module entry face in the AEDC VKF tunnel F hot shot facility. Heat transfer tests were completed in the Cornell Aeronautical Laboratory's 48-inch shock tunnel on the entry configuration through the Mach number range 6 to 17.

The H-1 command module model and the H-9 sphere model were tested at Mach 10 in the AEDC VKF tunnel C to compare the heating rates on the face of the command module to those on a sphere of equal radius. A test was conducted in the Langley unitary plan wind tunnel on the entry configuration and the HL-1 launch configuration in the Mach number range from 2.5 to 3.7 to determine the effect of the strakes on the heating distribution. Additional information on the effects of the strakes, as well as the effects of the new launch escape tower configuration, was obtained in the AEDC VKF tunnel C at Mach 10.

Tests to obtain real gas effects on the heat transfer data over the entry face of the command module will be conducted in ballistic ranges and in plasma jet tunnels on the H-12 model. Plasma jet facilities, which are in the development stages, are currently being evaluated to select a suitable tunnel.

Two tests are planned for the immediate future. A heat transfer test in the LAD 12-inch shock tunnel will be run at Mach number 10 to 12 to determine leeward afterbody heating rates. The models will be wire-mounted to eliminate sting support effects.

Cornell Aeronautical Laboratory is constructing an 8-foot shock tunnel in which a 2- to 4-foot Apollo model can be tested to obtain heating for RCS apertures, windows, and protuberances. Instrumentation concentration in areas of special interest also may be achieved. Testing will be contingent on the completion and check-out of the shock tunnel.

15.3 TEST PROGRAM

The wind tunnel test program is divided into four phases to provide information for a man-rated spacecraft:

1. Preliminary design data uses idealized aerodynamic configurations for models.

2. Design confirmation models are updated to include effects of small asymmetries and surface irregularities that have been included in the vehicle design.

3. Production configuration evaluation models are updated to include the final production vehicle design.

4. Flight test support and modifications tests are specifically redesigned to support flight tests (e.g. boilerplate) or to evaluate recommended modifications as a result of flight test data.

The lower ranges of velocity and altitude encountered by the Apollo vehicle will be investigated by means of well-established wind tunnel techniques. Entry into the atmosphere will engender conditions that require new techniques. Several types of facilities must be used to obtain specific data for which each is best suited. In shock or hot-shot tunnels, for example, static stability and control effectiveness will be determined by use of very light-in-weight models mounted on internal strain-gage balances. In free-flight wind tunnels the trajectory of the model will be recorded by a series of shadow-graphs and analyzed to yield the required force data and dynamic coefficients. Dynamic stability is best evaluated in conventional supersonic wind tunnels by means of a dynamic balance. The model is forced to oscillate about a set angle of attack, and damping derivatives are determined from analysis of data with and without air flow over the model. Free damped oscillation techniques will also be used to determine damping derivatives.

Aerodynamic heating rates will be determined from output measurements of thin-film or variable reluctance heat transfer gauges, or from the temperature-time histories of thermocouples mounted on the inner surface of a thin-walled model. Data will be obtained from models tested in both shock tunnels and continuous flow tunnels. In free-flight wind tunnels, heating measurements will be made either by determination of the output of a single thermocouple, inductively, or by use of a miniature FM telemeter transmitter.

Radiative heating will be measured in the free-flight wind tunnel by means of a photomultiplier pickup in combination with a series of

[redacted]

monochromators. This instrumentation yields the energy wave length distribution of the glowing gas cap ahead of the model.

Heat transfer to the inside of the command module RCS nozzles from external flow has been simulated in a Mach 3 blowdown tunnel at the NAA-Los Angeles division.

15.4 EQUIPMENT REQUIREMENTS (MODELS)

The following models are required for testing to obtain the necessary data for the Apollo program. Figure 15-1 shows the following principal Apollo test configurations: launch configuration, launch escape vehicle, command module, and command module with service module.

15.4.1 Static Force (FS) Models

FS-1 A 0.02-scale model of the command module with several detachable escape tower configurations incorporating provisions for simulation of jet plume from escape motor.

FS-2 A 0.105-scale model of the command module with several detachable escape tower configurations. The large scale of this model will provide high Reynolds number data.

FS-3 A 0.045-scale model of the command module with detachable escape tower configuration. This model is designed for high-temperature flow.

FS-4 A lightweight 0.04-scale model of the command module for testing in impulse tunnels.

FS-6 A 0.013-scale model of the command module for testing in high-enthalpy flow in the entry attitude. This model will be fabricated and tested by NASA Ames Research Center.

FS-7 A 0.02-scale model of the command module with a parametrically varied shape.

FS-8 A lightweight 0.05-scale model of the command module for testing in impulse tunnels.

FS-9 A 0.105-scale model of the command module with apex drogue chute cover removed.

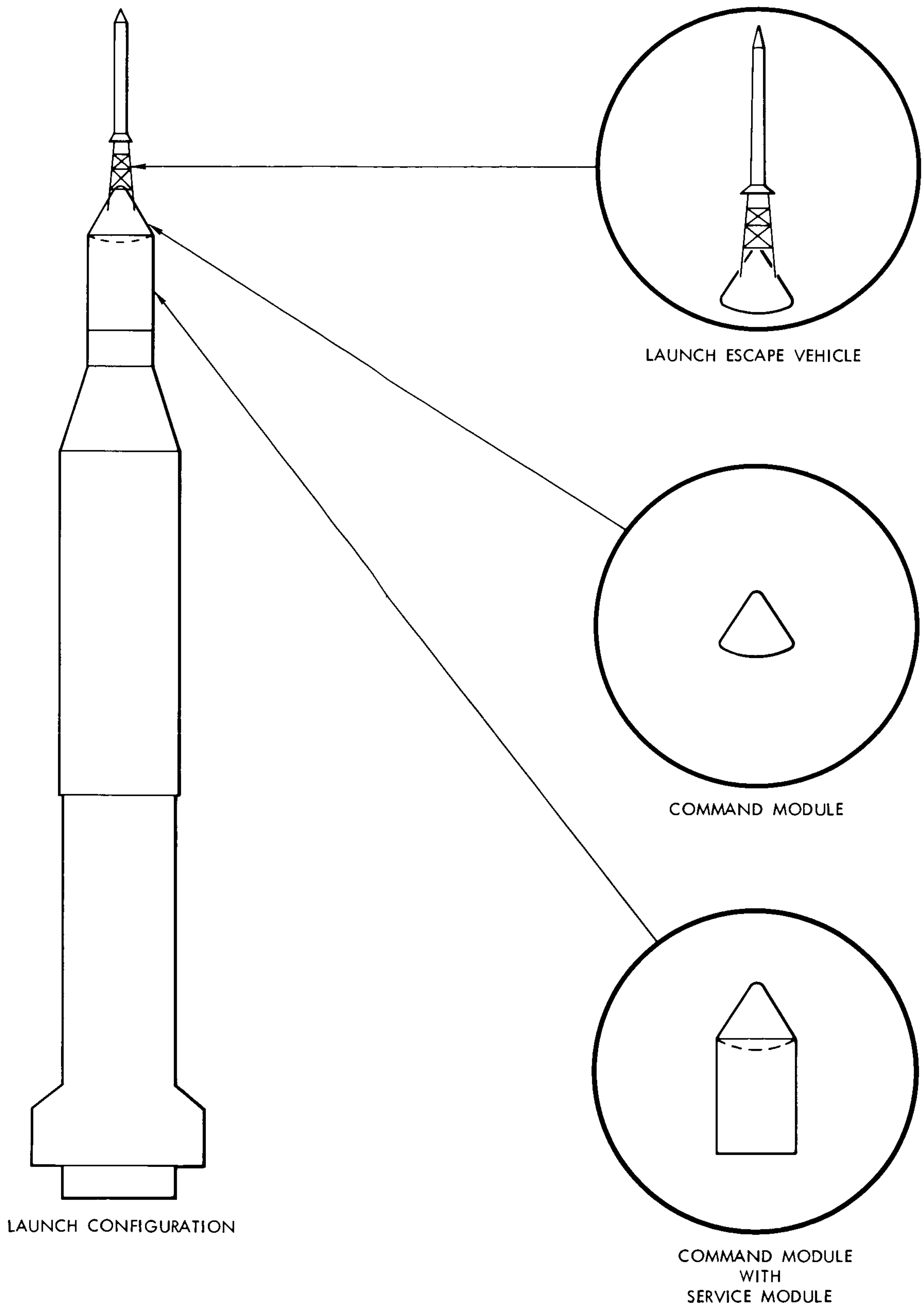

Figure 15-1. Apollo Test Configurations

[redacted]

FSC-1 A 0.10-scale drogue chute model with fixed command module. Three parachute diameters with various porosities and various riser elasticities will be tested. The models will include a drag balance for measuring the drag force of the chute.

FDC-1 A 0.10-scale dynamically similar command module with the drogue chute. The command module will be mounted for three degrees of freedom. The drogue chute diameter, porosity, and riser length and elasticity will be determined from the FSC-1 tests.

FSJ-1 A 0.085-scale H_2O_2 hot jet model of the launch escape vehicle that will be used to determine the effects of the launch escape motor exhaust plumes on LEV forces, pressures, and static stability in the transonic Mach number range.

FSJ-3 A 0.045-scale cold air flow model of the launch escape vehicle that will be used to determine the effects of the launch escape motor exhaust plumes on LEV forces, pressures and static stability in the supersonic Mach number range.

FSL-1 A 0.02-scale model of the complete launch (L) configuration with the Saturn I launch vehicle. Provisions for detaching the escape tower, the command module, and the service module will be provided to obtain the characteristics of the booster alone.

Ringsail No. 1 Full, one-half, and one-third scale models of the 1543-501 main Apollo parachute. Solid parachutes having hemispherical, flat, and conical gore shapes (all approximately 28 feet in diameter) were also tested.

Ringsail No. 2 One-third scale models of modified 1543-501 ringsail parachutes. The modifications will be determined from the results of the ringsail No. 1 test.

15.4.2 Dynamic Force (FD) Models

FD-1 Two 0.03-scale models of the command module, one with the center of gravity on the center line and the other with an off-set center of gravity. Models will be of lightweight construction and will be mounted on air bearings.

FD-2 A 0.055-scale model of the command module with a detachable escape tower. Model is of lightweight and relatively simple construction to permit early testing.

FD-3 A 0.045-scale model of the command module with a detachable escape tower.

FD-4 A 0.10-scale model of the command module with a detachable escape tower. This model is being fabricated and tested by the NASA Langley Research Center.

[redacted]

FD-5 A 0.05-scale model of the command module and a 0.059-scale model of the launch escape vehicle. Models are of lightweight construction to be mounted on gas and ball bearings.

FD-6 0.10-scale dynamic models of the command module and launch escape vehicle will be used for tumbling dynamic tests. Models will be of lightweight construction and will be mounted on gas and ball bearings.

FD-8 The 0.10-scale modified FDC-1 model for use during tumbling dynamic tests. The model is of lightweight construction and is mounted on a ball bearing.

15.4.3 Structural Dynamic (SD) Models

SD-1 A 0.08-scale model of the SA-5 launch configuration. The model is flexible with scale stiffness distribution and variable mass distribution for simulating the correct mass at Mach numbers 0.8, 1.0, and 1.2. The model is spring-mounted to allow bending in the first and second free-free bending modes, as well as pitch oscillation about the center of gravity. Instrumentation includes bending moment strain gauges, accelerometers, and transducers for measuring transient pressures. An electromagnetic shaker installed between the sting and model is used to excite the model to obtain aerodynamic damping in pitch.

15.4.4 Static Pressure (PS) Models

PS-1 A 0.02-scale model of the command module with detachable escape tower configurations. This model is instrumented with pressure taps for obtaining pressure distributions on the command module with and without the escape tower installed.

PS-3 A 0.045-scale model of the command module with detachable service module and escape tower configurations. This model is instrumented with pressure taps for obtaining pressure distributions on the escape motor, command module, and service module.

PS-4 A 0.04-scale model of the command module. This model is instrumented with miniature pressure transducers to obtain pressure distributions in impulse tunnels.

[redacted]

PS-5 A 0.05-scale model of the command module instrumented with miniature pressure transducers to obtain pressure distributions in impulse tunnels.

PS-6 A 0.01875-scale model of the command module instrumented with miniature pressure transducers to obtain pressure distributions in impulse tunnels.

PS-7 A 0.125-scale model of the command module instrumented with miniature pressure transducers to obtain pressure distributions in impulse tunnels.

15.4.5 Static and Transient Pressure (PST) Models

PSTL-1 A 0.055-scale model of the launch (L) configuration with only the forward portion of the Saturn 1 launch vehicle duplicated. This model has provisions for detaching the escape tower. This model is instrumented with static pressure taps and acoustical pickups to obtain static and transient pressure distributions on the command module, the service module, and the Saturn-IV.

PSTL-2 This model will simulate the Saturn 1B and IV launch configurations. All windows and protuberances are included on this model. The instrumentation consists of static and transient pressure taps for obtaining pressure distributions over the forward portion of the launch vehicle and spacecraft.

15.4.6 Heat Transfer (H) Models

H-1 A thin-skin 0.02-scale model of the command module, plus service module and launch escape system, instrumented with thermocouples to obtain heat transfer rates. The service module also is instrumented with pressure taps.

H-2 0.045-scale models of the command module, launch escape system, and service module. These models are constructed with thin skins and are instrumented with thermocouples to obtain heat transfer rates.

H-4 A 0.05-scale model of the command module for testing in impulse tunnels. This model was instrumented with thin-film resistance thermometers to obtain heat transfer rates.

FD-5 A 0.05-scale model of the command module and a 0.059-scale model of the launch escape vehicle. Models are of lightweight construction to be mounted on gas and ball bearings.

FD-6 0.10-scale dynamic models of the command module and launch escape vehicle will be used for tumbling dynamic tests. Models will be of lightweight construction and will be mounted on gas and ball bearings.

FD-8 The 0.10-scale modified FDC-1 model for use during tumbling dynamic tests. The model is of lightweight construction and is mounted on a ball bearing.

15.4.3 Structural Dynamic (SD) Models

SD-1 A 0.08-scale model of the SA-5 launch configuration. The model is flexible with scale stiffness distribution and variable mass distribution for simulating the correct mass at Mach numbers 0.8, 1.0, and 1.2. The model is spring-mounted to allow bending in the first and second free-free bending modes, as well as pitch oscillation about the center of gravity. Instrumentation includes bending moment strain gauges, accelerometers, and transducers for measuring transient pressures. An electromagnetic shaker installed between the sting and model is used to excite the model to obtain aerodynamic damping in pitch.

15.4.4 Static Pressure (PS) Models

PS-1 A 0.02-scale model of the command module with detachable escape tower configurations. This model is instrumented with pressure taps for obtaining pressure distributions on the command module with and without the escape tower installed.

PS-3 A 0.045-scale model of the command module with detachable service module and escape tower configurations. This model is instrumented with pressure taps for obtaining pressure distributions on the escape motor, command module, and service module.

PS-4 A 0.04-scale model of the command module. This model is instrumented with miniature pressure transducers to obtain pressure distributions in impulse tunnels.

[redacted]

PS-5 A 0.05-scale model of the command module instrumented with miniature pressure transducers to obtain pressure distributions in impulse tunnels.

PS-6 A 0.01875-scale model of the command module instrumented with miniature pressure transducers to obtain pressure distributions in impulse tunnels.

PS-7 A 0.125-scale model of the command module instrumented with miniature pressure transducers to obtain pressure distributions in impulse tunnels.

15.4.5 Static and Transient Pressure (PST) Models

PSTL-1 A 0.055-scale model of the launch (L) configuration with only the forward portion of the Saturn 1 launch vehicle duplicated. This model has provisions for detaching the escape tower. This model is instrumented with static pressure taps and acoustical pickups to obtain static and transient pressure distributions on the command module, the service module, and the Saturn-IV.

PSTL-2 This model will simulate the Saturn 1B and IV launch configurations. All windows and protuberances are included on this model. The instrumentation consists of static and transient pressure taps for obtaining pressure distributions over the forward portion of the launch vehicle and spacecraft.

15.4.6 Heat Transfer (H) Models

H-1 A thin-skin 0.02-scale model of the command module, plus service module and launch escape system, instrumented with thermocouples to obtain heat transfer rates. The service module also is instrumented with pressure taps.

H-2 0.045-scale models of the command module, launch escape system, and service module. These models are constructed with thin skins and are instrumented with thermocouples to obtain heat transfer rates.

H-4 A 0.05-scale model of the command module for testing in impulse tunnels. This model was instrumented with thin-film resistance thermometers to obtain heat transfer rates.

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H-6 A 0.01875-scale model of the command module instrumented with thin-film platinum resistant heat transfer gauges for obtaining heat transfer rates.

H-7 A 0.040-scale thick-skin, stainless steel model of the command module instrumented with thin wafer calorimeters and tested in hot-shot tunnels.

H-9 A thin-skin, stainless steel sphere having the same diameter as the entry face of the H-1 model and instrumented with thermocouples.

H-11 0.20-scale model of the actual flight configuration instrumented with thin-film platinum heat transfer gages. This model will be used to obtain heat transfer distributions in the vicinity of holes, windows, and protuberances. The model will be tested in an impulse tunnel.

H-12 Deleted.

H-14 Deleted.

HBR-1 A 0.45-inch diameter model of the command module for testing in a ballistic range facility. Approximately fifteen of these models will be required. These models will be fabricated and tested by the Ames Research Center.

HL-1 A 0.045-scale model of the launch configuration with only the forward portion of the Saturn 1 launch vehicle duplicated. This model will be constructed with a thin skin and will be instrumented with thermocouples to obtain heat transfer rates. This model is made with some modified parts of the H-2. These parts are interchangeable with the original H-2 configuration.

HL-1B A modification of the Saturn booster flare angle on the HL-1 model from 13 to 25 degrees to simulate the S-IVB stage.

[redacted]

HM-1 0.040-scale model of the Mercury entry configuration to determine the validity of afterbody heat transfer measurement in the LAD 12-inch shock tunnel. The model will be made of wood and will be instrumented with thin-film resistance gages.

15.5 TEST FACILITIES

The Apollo wind tunnel test program has taken into account the wide range of flight conditions that the spacecraft will encounter from launch to entry and recovery. To obtain data applicable to these conditions, many types of facilities will be used. These facilities are listed with a brief description of their characteristics. The capability of these facilities to simulate the Apollo boost and entry trajectories is graphically presented in Figures 15-2 and 15-3.

15.5.1 Continuous Tunnels

North American Aerodynamics Laboratory - 7.75-by 11-foot low-speed wind tunnel. A Mach number of approximately 0.2 can be obtained at a Reynolds number of approximately 1.44×10^6 per foot.

North American Columbus Division Aerodynamics Laboratory - 7- by 10-foot subsonic wind tunnel. A Mach number range from 0.05 to 0.39 can be obtained at a Reynolds number of approximately 2.7×10^6 per foot.

Langley - 20-foot free-spinning tunnel. A velocity of 0 to 66 mph can be obtained at a Reynolds number range from 0 to 0.62×10^6 per foot.

Langley - 12-foot low-speed tunnel. A velocity of 40 to 50 mph is obtainable in this tunnel.

Langley - 8-foot transonic pressure tunnel. Mach numbers from 0 to 1.2 are available over a Reynolds number range from 1 to 4 $\times 10^6$ per foot.

Langley - unitary plan wind tunnel. Two 4- by 4-foot test sections are used. One covers Mach numbers from 1.5 to 2.8, and the other Mach numbers from 2.6 to 5 at Reynolds numbers up to 10×10^6 per foot.

[redacted]AL

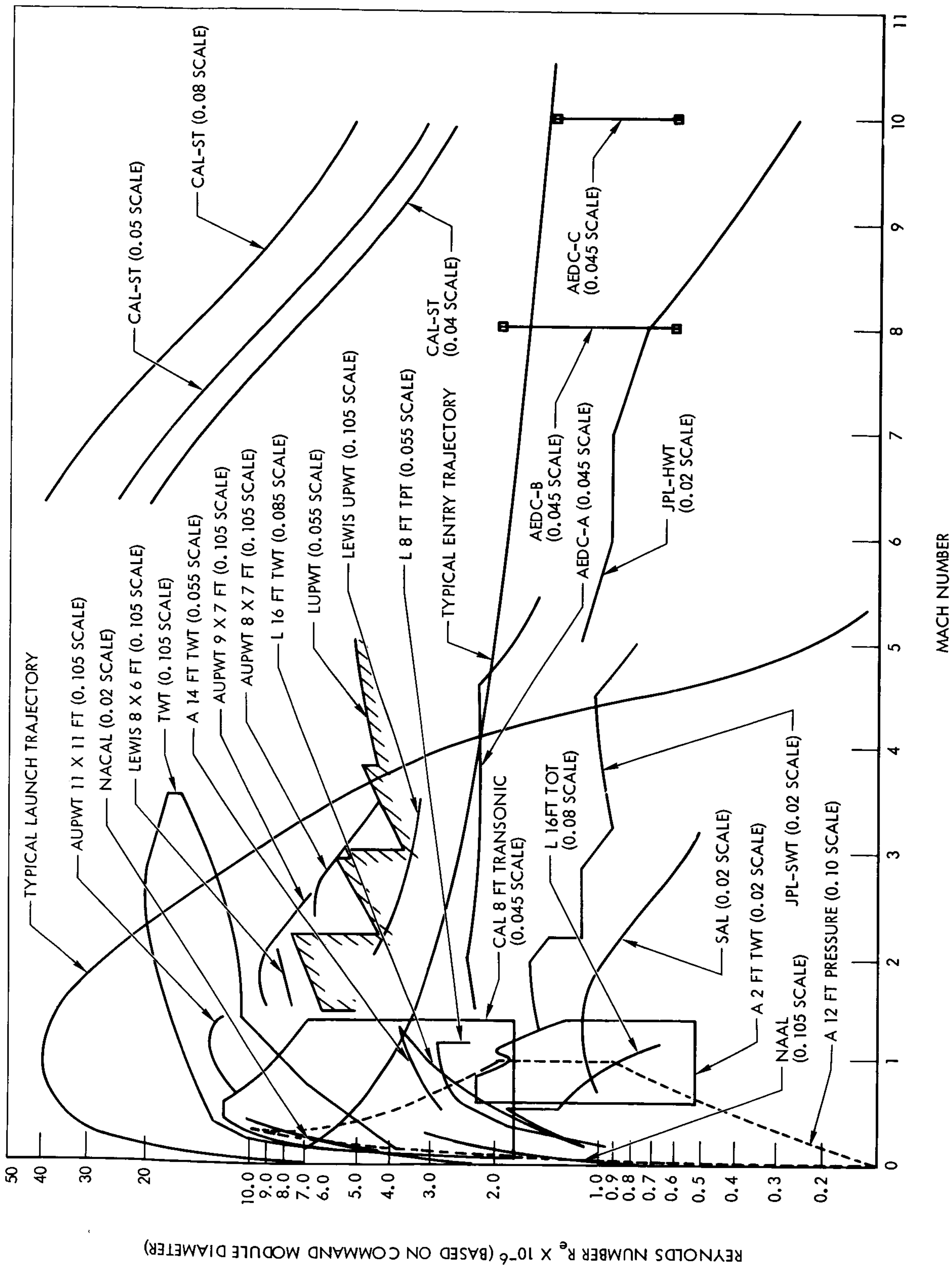

Figure 15-2. Test Facilities Capabilities (Reynolds Number Versus Mach Number)

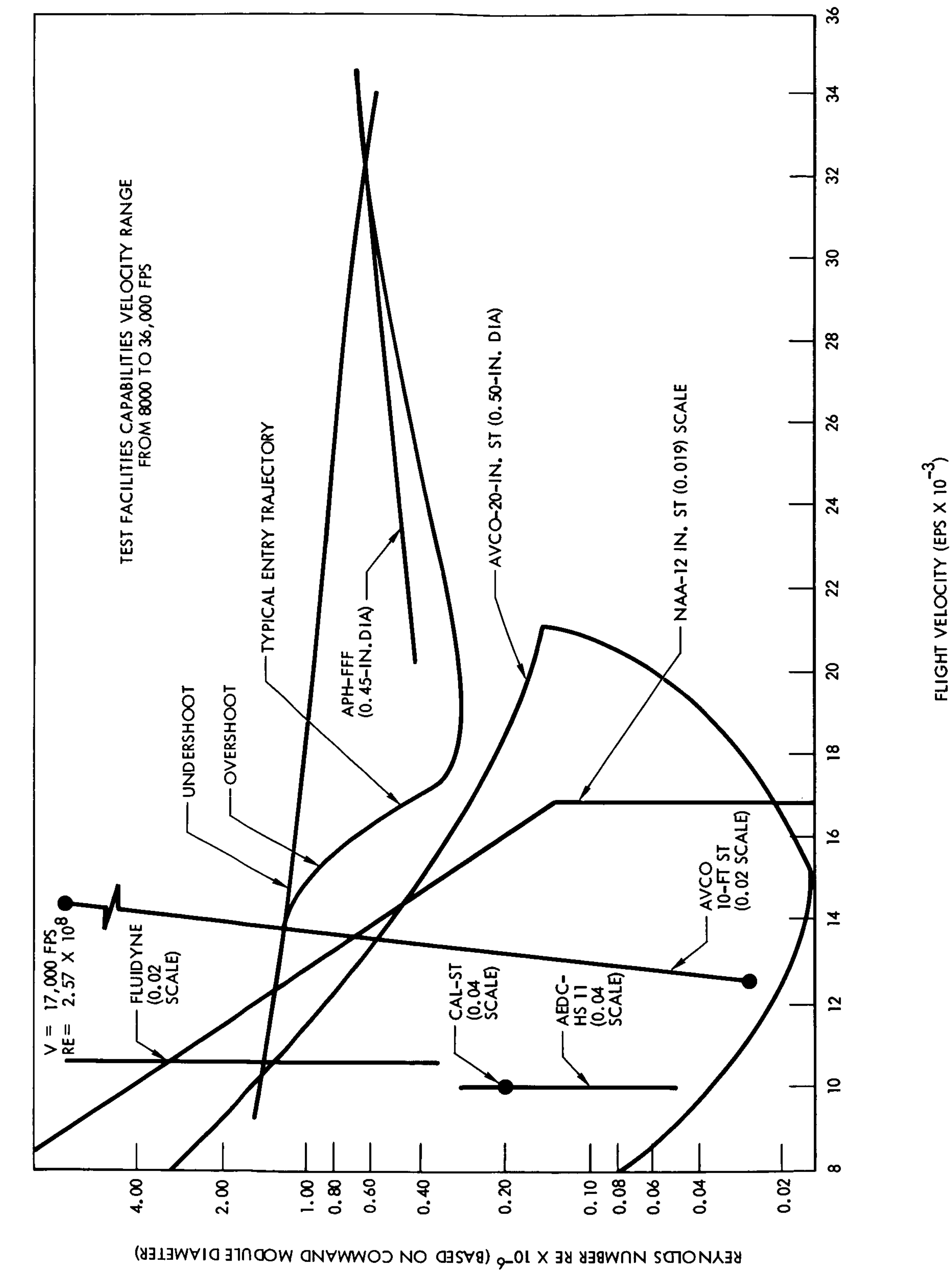

Figure 15-3. Test Facilities Capabilities (Reynolds Number Versus Velocity)

Langley – 16-foot transonic dynamics tunnel. Mach numbers from 0.3 to 1.2 can be obtained. Reynolds number varies from 0.04 x 10^6 to 9 x 10^6 per foot. The tunnel may be operated using either air or freon as the test media.

Langley – 16-foot transonic wind tunnel. Mach numbers from 0.2 to 1.3 can be obtained. Reynolds number varies from 1.2 x 10^6 to 4.15 x 10^6 per foot.

Jet Propulsion Laboratory – 20-inch supersonic wind tunnel. Mach numbers from 1.3 through 5 can be achieved, and Reynolds numbers between 0.4 x 10^6 and 6 x 10^6 per foot are obtained.

Jet Propulsion Laboratory – 21-inch hypersonic wind tunnel. This facility covers the Mach number range between 5 and 9.5 at Reynolds numbers from 0.25 x 10^6 to 3.6 x 10^6 per foot.

Arnold Engineering Development Center Von Karman Facility – 40-inch tunnel A. Mach numbers from 1.5 to 6 can be obtained, and a Reynolds number range from 0.3 x 10^6 to 9 x 10^6 per foot can be covered.

Arnold Engineering Development Center Von Karman Facility – 50-inch tunnel B. This tunnel operates at Mach number 8 over a Reynolds number range from 0.25 x 10^6 to 3.3 x 10^6 per foot.

Arnold Engineering Development Center Von Karman Facility – 50-inch tunnel C. A Mach number of 10 is obtained with a Reynolds number range from 0.29 x 10^6 to 2.5 x 10^6 per foot.

Ames – unitary plan wind tunnel. This facility has three test sections. The 11-foot test section covers the range from Mach number 0.7 to 1.4 at Reynolds numbers up to 8.5 x 10^6 per foot. The 9- by 7-foot test section operates between Mach number 1.5 and 2.6 at Reynolds numbers up to approximately 6 x 10^6. The 8- by 7-foot test section covers a Mach number range from 2.4 to 3.5 at Reynolds numbers up to the order of 3 to 5 x 10^6 per foot.

Ames – 14-foot transonic wind tunnel. This tunnel operates at Mach numbers from 0.6 to 1.2 at Reynolds numbers from 2.8 x 10^6 to 4.2 x 10^6 per foot.

Ames – 2-foot transonic wind tunnel. This tunnel operates at Mach numbers from 0 to 1.4 at Reynolds numbers from 2 x 10^6 to 8.4 x 10^6 per foot.

[redacted]

Ames — 6-inch arc jet tunnel. This tunnel operates at Mach numbers 10 and 16 with a stagnation enthalpy of 900 Btu/lb.

Ames — 12-foot pressure wind tunnel. This tunnel operates at Mach numbers 0 to 1.0 at Reynolds numbers from 0 to 9.2×10^6 per foot.

Ames — 7 by 10-foot low-speed tunnel. Velocities of 0 to 300 mph are obtainable in this tunnel.

Ames — 40 by 80-foot low-speed continuous tunnel. This tunnel operates at velocities from 0 to 200 knots at Reynolds numbers from 0 to 2.1×10^6 per foot.

15.5.2 Intermittent Tunnels

North American Aviation — Supersonic Aerophysics Laboratory. Mach numbers of 0.7 and from 1.56 through 3.75 and Reynolds numbers between 3.88×10^6 and 2.26×10^6 per foot are obtained in this tunnel.

North American Aviation — 7 by 7-foot trisonic wind tunnel. Mach numbers from 0.2 to 3.5 are available, and Reynolds numbers from 5×10^6 to 14×10^6 per foot can be obtained.

Fluidyne — 20-inch Mach number 14 hypersonic tunnel. Reynolds numbers from 0.028×10^6 to 0.6×10^6 per foot can be obtained.

15.5.3 Impulse Tunnels

Arnold Engineering Development Center Von Karman Facility — 100-inch tunnel F and 50-inch hot-shot II. These tunnels currently operate with nitrogen as a test medium at Mach numbers from 16 to 21. Stagnation pressure is normally 1000 atmospheres.

Avco — 20-inch shock tunnel Mach numbers from 8 to 28 can be obtained with a Reynolds number range from 10^3 to 1.2×10^5 per foot.

Cornell Aeronautical Laboratory — 24- and 48-inch shock tunnels. Mach numbers from 5 to 18 can be obtained with a Reynolds number range from 0.03×10^6 to 10×10^6 per foot at the lower Mach number.

Cornell Aeronautical Laboratory — 6-foot shock tunnel. Mach numbers from 10 to 30 are available, and a Reynolds number range from 2×10^2 to 5×10^5 per foot can be obtained.

North American Aviation — 12-inch shock tunnel. Mach numbers from 7 to 22 can be obtained with a Reynolds number range from 0.0001×10^6 to 5×10^6 per foot.

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15.5.4 Free-Flight Facilities

Ames Prototype Hypersonic Free-Flight Facility. Velocities up to 40,000 fps are obtained by firing models approximately 0.45 inches in diameter into a hypersonic shock tunnel.

15.6 TEST SCHEDULES

The wind tunnel test schedule is shown in Figure 15-4.

[redacted]

[redacted]

TYPE DATA	MODEL DESIG	CONFIGURATION	C/M DIA IN.	PRINCIPLE TEST OBJECTIVES	1962	1963	1964	1965
PRESSURES - STEADY STEADY STATE AND TRANSIENT	PS-1		3"	INITIAL PRESSURE DISTRIBUTION ON COMMAND MODULE WITH AND WITHOUT ESCAPE TOWER INSTALL.	JLP AMF			
	PS-3		7"	MORE COMPLETE PRESSURE DISTRIBUTION ON COMMAND MODULE AND SERVICE MODULE IN MACH 5-10 RANGE	AEDC TWT	AEDC LANG		
	PS-4		6.2"	PRESSURE DISTRIBUTIONS IN HOT-SHOT TUNNELS IN MACH 16-21 RANGE	AEDC	AC		
	PS-5		7.7"	PRESSURE DISTRIBUTIONS WITH SOME REAL GAS EFFECTS IN MACH 10-30 RANGE	CAL	CAL		
	PS-6		2.9"	PRESSURE DISTRIBUTION OVER C/M	12 'SHOCK			
	PS-7		7.7"	PRESSURE DISTRIBUTION WITH SOME REAL GAS EFFECTS IN MACH 10-30 RANGE			CAL	
	PSTL-1		8.5"	STEADY STATE AND TRANSIENT MEASURE ON THE SATURN I LAUNCH CONFIGURATION	TWT AMES UNIT			
	PSTL-2		8.5"	STEADY STATE AND TRANSIENT MEASURE ON THE SATURN IB & V LAUNCH CONFIGURATION	AMES TRANS.	AMES		
HEAT TRANSFER	H-1		3.1"	INIT HEAT TRANS DIST ON C/M LES AND C/M + S/M; MACH NO. RANGE OF 6 TO 9	JPL AEDC			
	H-2		6.9"	HEAT TRANSFER DISTRIBUTION ON C/M, LAUNCH ESCAPE SYSTEM AND C/M + S/M; MACH NO. RANGE OF 2.4 TO 12	AEDC	LANG AEDC	AEDC	
	H-3		2"	HEAT TRANS DATA AT HIGH ENTHALPY CONDITIONS IN A MACH RANGE OF 1 TO 3	AMES AMES		AMES	
	H-4		7.7"	HEAT TRANS DATA AT HIGH ENTHALPY CONDITION IN MACH 10-20 RANGE	CAL	CAL	CAL	
	H-6		2.9"	HEAT TRANS DATA USING THIN FILM PLAT RESISTING HEAT TRANSFER GAGES	12" SHOCK TUNNEL			
	H-7		6.2"	HEAT TRANSFER DATA IN HOT-SHOT TUNNEL USING THIN WAFER CALORIMETERS	AEDC "F"			
	H-9	SPHERE	7.4" DIA	HEAT TRANS DATA FROM THIN-SKIN SPHERE WITH DIA OF HEAT SHIELD	AEDC			
	H-11		31"	HEAT TRANS DATA FROM WOOD MODEL OF ACTUAL FLIGHT CONFIG			CAL	
	H-12		3.1"	HEAT TRANS DATA AT VERY HIGH STAGNATION ENTHALPY CONDITION		FACILITY TO BE DETERMINED LATER		
	HBR-1		0.45"	STAGNATION HEATING RATES AT PROPER ENTHALPIES AND GAS CAP RADIATION	AMES PHFFF	AMES PHFFF AMES PHFFF	AMES	
	HL-1		6.9"	HEAT TRANSFER DISTRIBUTION ON A SIM FWD PORT OF THE SATURN I LAUNCH CONFIGURATION	AEDC	LANG.	AEDC	
	HL-1B		6.9"	HEAT TRANSFER DISTRIBUTION ON A SIM FWD PORT OF THE SATURN IB LAUNCH CONFIGURATION	AEDC	LANG.	AEDC	
	RING SAIL #1					AMES		
	RING SAIL #2						AMES	

Figure 15-4. Apollo Wind Tunnel Test Program (Sheet 1 of 2)

[redacted]

[redacted]

TYPE DATA	MODEL DESIG	CONFIGURATION	C/M DIA IN.	PRINCIPLE TEST OBJECTIVES	1962 (J F M A M J J A S O N D)	1963 (J F M A M J J A S O N D)	1964 (1 2 3 4)	1965 (1 2 3 4)
STATIC STABILITY AND CONTROL	FS-1		3"	INITIAL AERO CHARACTERISTICS OF COMMAND MODULE AND VARIOUS LAUNCH ESCAPE SYSTEM CONFIGURATION	SAL JPL SAL SAL AMES AMES			
	FS-2		16"	1. SAME AS FS-1 AT HIGHER R_e NO. 2. LOADS ON INDIVIDUAL CONR OF LES	AMES TWT AMES TWT NAAL AMES	AMES TWT TWT AMES TWT	TWT AMES AMES	
	FS-3		7"	STABILITY DATA FOR COMMAND WITHOUT SERVICE MODULE	AEDC	AEDC AEDC AEDC AEDC	AEDC AEDC	
	FS-4		6"	STABILITY DATA FOR COMMAND IN HOTSHOT TUNNELS WITH M = 16-21 RANGE	AEDC			
	FS-6		2"	STABILITY DATA IN HIGH ENTHALPY CONDITIONS IN MACH 12-14 RANGE	AMES			
	FS-7		3"	STABILITY CHARACTERISTICS OF COMMAND MODULE WITH PARAMETRICALLY VARIED SHAPE	JPL			
	FS-8		7.7"	STABILITY DATA FOR COMMAND MODULE IN MACH 10-30 RANGE	CAL			
	FS-9		16"	STABILITY OF COMMAND MODULE WITH DROGUE CHUTE COVER REMOVED	NAAL			
	FSC-1		16"	STABILITY OF DROGUE CHUTE ALONE AND IN COMBINATION WITH COMMAND MODULE	NAAL			
	FDC-1		16"	DYNAMIC STABILITY OF DROGUE CHUTE IN COMBINATION WITH COMMAND MODULE	NAAL	LANGLEY NAAL		
	FSJ-1		4.6"	ESCAPE MOTOR "HOT" JET EFFECTS ON LAUNCH ESCAPE SYSTEM STABILITY	LANGLEY	LANGLEY LANGLEY	LANGLEY	
	FSL-1		3"	STABILITY DATA OF COMPLETE LAUNCH VEHICLE AND BOOSTER ALONE (SATURN I)	AEDC TWT AMES NACAL			
	FSJ-3		7"	ESCAPE MOTOR "COLD" JET EFFECT ON LEV STABILITY		AEDC AEDC		
DYNAMIC STABILITY	FD-1		4.6"	DYNAMIC STABILITY CHARACTERISTICS FOR C/M USING FREE OSC TECH IN MACH 3-9 RANGE	JPL			
	FD-2		8.5"	DYNAMIC STABILITY CHARACTERISTICS FOR C/M ALONE AND WITH LES CONFIG IN MACH RANGE 0.3-4.65	LANGLEY UNIT. TRAN UNIT LANGLEY			
	FD-3		6.9"	DYNAMIC STABILITY CHARACTERISTICS FOR C/M ALONE AND WITH LES CONFIG IN MACH RANGE 8.0 AND 10.	AEDC	AEDC	AEDC	
	FD-4		24"	DYNAMIC STABILITY CHARACTERISTICS FOR C/M IN LES CONFIGURATION IN SUBSONIC SPEED RANGE	LANGLEY LOW SPEED			
	FD-5		7.7"	DYNAMIC STABILITY CHARACTERISTICS FOR C/M & LES CONFIGURATION		AEDC AMES		
STR. DYN.	SD-1		12.3"	STRUCTURAL AND AERO DAMPING DER, BUFFETING EFFECTS AND SINGLE DOF	LANGLEY TRANS. DYN.			
	FD-6		15.4"	TUMBLING DYNAMIC STABILITY CHARACTERISTICS FOR C/M & LEV IN MACH RANGE 0.2 TO 0.9		AMES	AMES	
	FD-8		15.4"	TUMBLING DYNAMIC STABILITY CHARACTERISTICS FOR C/M & C/M WITH TOWER AT MACH 0.2		AMES		

Figure 15-4. Apollo Wind Tunnel Test Program (Sheet 2 of 2)

[redacted]

16.0 THERMAL PROTECTION SYSTEMS*

16.1 SCOPE

The thermal protection system for the spacecraft consists of three basic elements: the ablative material, the brazed-steel honeycomb substructure for the command module, and the thermal insulation for the command and service modules. In general, the tests of this system will be designed to simulate the anticipated flight environment of the Apollo spacecraft during the following phases: boost, abort, earth orbit, translunar, lunar orbit, lunar return, and earth entry.

Developmental tests will be conducted by the ablative material subcontractor to evaluate the ablative material and the composite heat shield components. These tests will, in the early stages of development, consist of small scale tests on the individual materials for thermal and mechanical properties and will subsequently progress to tests on composite panels 2 by 3 feet in size. NAA will conduct performance evaluation tests to assure conformance to the procurement specifications. These tests will consist of design data tests and analysis verification tests.

Among the developmental and evaluation tests planned for the thermal protection system are mechanical and physical tests, dynamic tests, structural integrity tests, and thermodynamic tests. Tensile, shear flexure, compressive strength, specific heat, thermal expansion coefficient, and thermal conductivity properties of the ablative materials will be determined. Acoustical and vibrational environments will be simulated. Adhesive bond and large composite panel thermal exposure tests to verify the structural integrity of the heat shield ablative material and substructure will form an integral part of the development program. Thermodynamic tests conducted in plasma-arc tunnels will be used to determine the performance of the ablative material when exposed to the thermal environments applicable to the Apollo program. Space environment tests will be performed, depending on the capabilities of the available test facilities, with AFRM 008 in the MSC space chamber (see SID 62-109-5).

Information will be obtained for verification of design parameters for evaluation of ablative and structural components and assemblies, and for confirmation of the final design configuration.

*Entire section reissued

[redacted]

In addition, the thermal and mechanical properties of the antenna window material, insulation materials, and structural materials will be determined, as required for thermal analysis for the Apollo spacecraft and Apollo systems.

16.2 SUBCONTRACTOR TEST PLAN

16.2.1 Objectives

16.2.1.1 Ablative Materials

These materials will be tested for thermal and mechanical properties under conditions simulating, as much as possible, the anticipated flight environment. In addition, physical-chemical properties, such as emissivity, absorptivity, and decomposition temperatures, will be determined.

16.2.1.2 Composite Panel Tests

Composite panels consisting of the ablative material bonded to the substructure will be tested to determine the mechanical properties of the composite unit. In addition, the thermal-structural stress characteristics of the composite structure will be determined for conditions predicted throughout the Apollo mission. An important part of this test program will consist of determining the effectiveness of various types of adhesives under the extreme temperature cycles of the Apollo mission.

16.2.2 Test Plan

16.2.2.1 Aerothermodynamic Data Tests

Convective and radiative heat-transfer distribution for basic configuration.

16.2.2.2 Materials Performance Evaluation Tests

1. Materials performance tests during ascent heating
2. Materials screening tests
3. Materials properties during ablation
4. Material performance in laminar and turbulent flow
5. Material surface properties: transmittance, reflectance, and emissivity

[redacted]

6. Materials response to combined radiative and convective heating

7. Materials response to simulated trajectories

16.2.2.3 Materials Properties Tests

1. Thermal properties of both virgin and char materials

2. Mechanical properties of both virgin and char materials

16.2.2.4 Structures Tests

1. Flexural tests of composite beams and panels

2. Shear tests of bonding material at various temperatures

3. Thermal cycling tests of ablator and composite panel at low temperatures

4. Acoustic tests

5. Mechanical vibration tests

6. Design verfication tests

7. Peel tests of bonding material over a temperature range of -260 F to +600 F

16.2.2.5 Qualification Tests on Composite 2- by 3-Foot Panels

1. Vibration tests for typical environments

   a. Ground handling
   b. Launch
   c. Boost
   d. Reentry

2. Shock tests - similar to vibration

3. Acceleration tests for typical flight environments

   a. Launch (7g to 15 milliseconds)
   b. Abort (3g lateral, 20g axial)
   c. Reentry (to 20g)

4. Induced time-temperature history test

5. Thermal-structural-stress analytical model

   a. Correlation of test data with predicted results
   b. Extrapolation to flight conditions
   c. Selection of qualification tests on basis of analytical model

16.3 S&ID TEST PLAN

16.3.1 <u>Heat Shield Ablator and Substructure Materials</u>

16.3.1.1 Objective

The heat shield materials will be tested for thermal and mechanical characteristics over the range of environmental conditions anticipated under flight conditions. These tests will include (but not be limited to) the determination of thermal conductivity, heat capacity, and coefficient of thermal expansion, as well as vibration, flexure, and acoustic.

16.3.1.2 Test Plan

1. Thermal properties

   a. Thermal conductivity, heat capacity, density for virgin and charred ablator

   b. Effective heat of ablation, decomposition, and temperature profile through material

2. Mechanical properties

   a. Flexural strength and modulus
   b. Tensile strength and modulus
   c. Compression strength and modulus
   d. Bearing strength
   e. Poisson's ratio
   f. Panel shear
   g. Hardness
   h. Bonding and/or fastener

      (1) Tensile lap shear
      (2) Flatwise tensile
      (3) Block shear
      (4) Peel

16.3.2 Protuberances and Obstructions

16.3.2.1 Objective

Protuberances and obstructions will be tested to determine their performance under simulated entry conditions and to determine their effect on the surrounding ablator.

16.3.2.2 Test Plan

Full size or scale models of the following components will be tested in plasma jet or radiant heat facilities.

1. C/M-S/M umbilical
2. C/M vent
3. Scimitar antenna
4. Antenna windows
5. Window assemblies
6. Shear pad with tension tie bolts

16.3.3 Thermal Insulation

16.3.3.1 Objectives

The objectives of the insulation testing program are:

1. To evaluate candidate insulations for thermal and mechanical properties under simulated space environments
2. To select those materials having optimum desirable properties for use in the Apollo thermal protection system. (These materials will be evaluated in actual installed configurations to determine optimum fastening and installation techniques.)

16.3.3.2 Test Plan

Heat capacity measurements will be determined for the temperature range of -150 F to +1000 F by using the closed cup drop calorimeter method. Thermal conductance determinations will be performed using three methods:

1. Guarded hot plate (temperature range +90 F to +1000 F)

2. Liquid nitrogen comparator (-150 F to +300 F)

3. Liquid nitrogen guarded heater (-300 F to -30 F). Special fabricated specimens representing actual configurations will be tested to determine thermal properties and to develop insulation installation and fastening techniques.

16.3.3.3 Equipment

The following test equipment will be required:

1. Closed cup drop calorimeter

2. Guarded hot plate conductivity apparatus

3. Liquid nitrogen comparator

4. Liquid nitrogen guarded heater

5. Temperature recorders, potentiometers, vacuum pumps, and related laboratory equipment

16.3.3.4 Facilities

The tests will be performed at the S&ID EDL facilities.

16.3.3.5 Test Schedule

The thermal protection systems test schedule is presented in Figure 16-1.

16.3.4 Evaluation of the Service Module Sextant Insulation

16.3.4.1 Objectives

The objectives for evaluating the S/M sextant insulation are:

1. Determine the effective thermal conductances for insulation installed in the proposed configurations

2. Determine the relative effectiveness of the proposed insulation configurations

3. Determine the percentage of heat transfer due to structural heat shorts versus the percentage lost by radiation for the propellant tanks

4. Develop and evaluate manufacturing skill in insulation blanket fabrication and installation

16.3.4.2 Test Plan

The S/M propellant sextant will be exposed to 10^{-5} torr and temperatures of -300 F and +250 F. The sextant will be held at each temperature and 10^{-4} torr for a maximum of five days, depending upon the thermal response time of the structure. Thermocouples that are located at key positions will be monitored to determine time-temperature histories, temperature gradients, heat loss paths, and the effective thermal conductivity of the insulated system.

16.3.4.3 Equipment

1. Vacuum chamber (10^{-5} torr)

2. LN_2 shroud

3. Heating blankets

4. Temperature recorders

16.3.4.4 Facilities

The tests will be performed at the LAD Apollo vacuum chamber. Manufacturing of the propellant sextant and the insulation blankets will be performed at S&ID.

16.3.4.5 Test Schedule

The service module sextant insulation test schedule is presented in Figure 16-1.

[redacted]

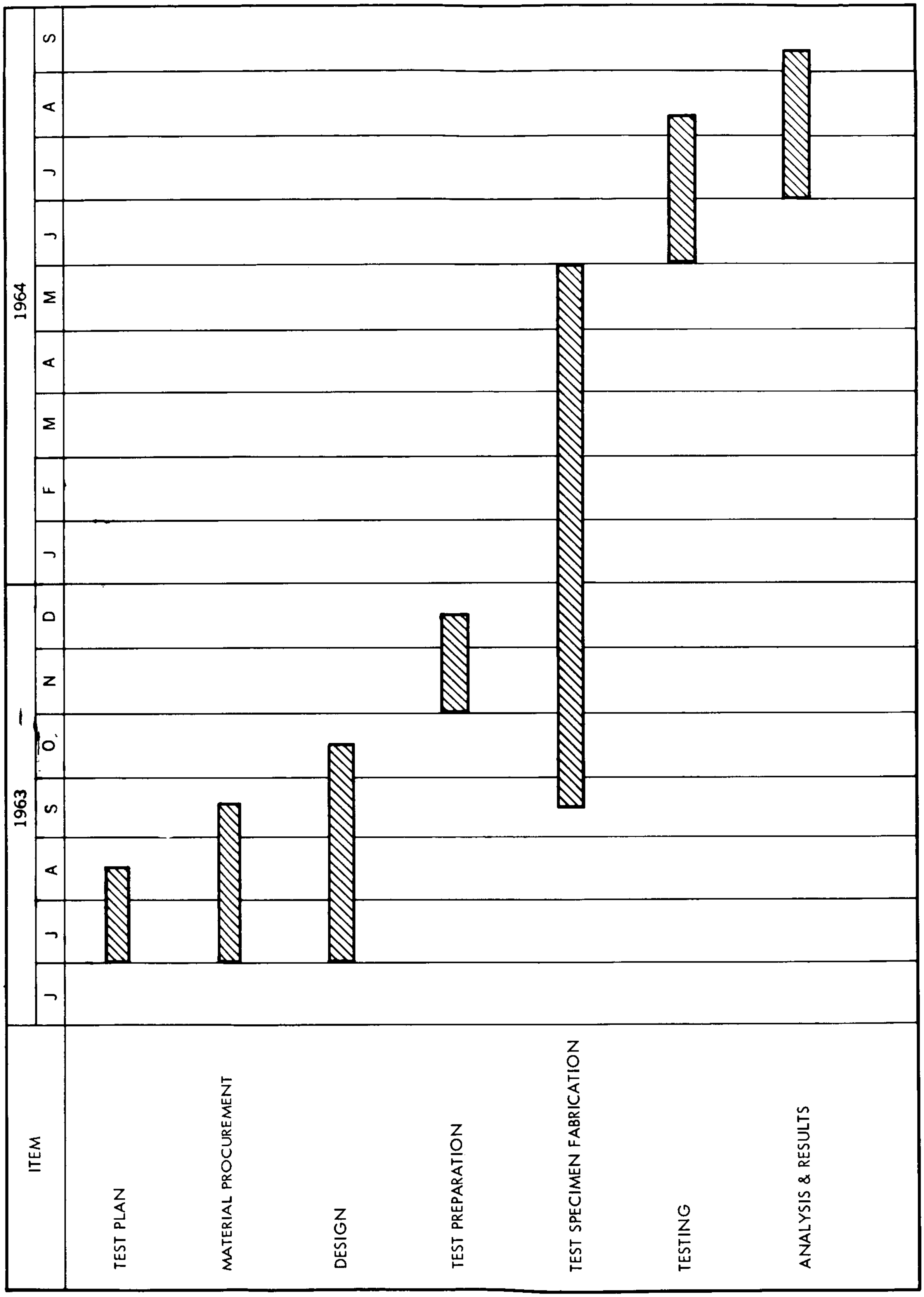

Figure 16-1. Service Module Sextant Insulation Test Schedule

[redacted]

[redacted]

17.0 IN-FLIGHT TEST SYSTEM

17.1 SCOPE

Efforts concerning the design verification, evaluation, qualification, and reliability testing of the in-flight test system will be specifically divided between the subcontractor and S&ID. Test programs conducted by the subcontractor and S&ID will be integrated to the extent necessary to avoid redundancy and to provide a maximum confidence level in system performance and reliability.

The in-flight test system procurement, as of 1 August 1963, has not been placed; therefore, this section must await submission of the Preliminary Test Plan and the hardware delivery schedule by the selected subcontractor.

[redacted]

[illegible]

18.0 DISPLAYS AND CONTROLS

18.1 SCOPE

Panel assemblies furnished complete by the associate contractor or subcontractor will be tested by the associate contractor or subcontractor.

Panel assemblies fabricated and assembled in-house will be tested by NAA. The major components, such as meters, switches, etc., to be assembled into these panels will be tested by their respective subcontractors.

The main display console will be tested by NAA.

18.2 SUBCONTRACTOR TEST PLAN

The respective contractors will be responsible for performing the required development, acceptance, and qualification tests with the concurrency of the responsible design group—G&N, SCS, etc. The following panel assemblies are in this category:

1. Entry monitor display panel assembly
2. Flight director attitude indicator panel assembly
3. Attitude set and GPD panel assembly
4. ΔV display panel assembly
5. SCS control and mode select panel assembly
6. G&N computer control panel assembly

18.3 S&ID TEST PLAN

18.3.1 Panel Assembly In-House Fabrication and Assembly

The development, acceptance, and ground qualification tests of components and panel assemblies are the responsibility of the Displays and Controls group. The following panel assemblies are in this category:

1. Barometric indicator
2. Emergency detection system and sequencer display

3. SCS control and mode select

4. Master caution, UHF antenna select

5. Master caution

6. Reaction control system

7. Radiation, audio, cryogenic and ECS

8. Reaction control system

9. Crew safety control

10. O_2 warning

11. Fuel cells, electrical power system

12. Antenna control system

13. Communication, data link and service propulsion system

18.3.1.1 Major Purchased Components

Major components, such as the baro indicator, toggle switches, rotary switches, meters, and other special items purchased from subcontractors, will be tested by development tests to ascertain optimum operational verification, by acceptance tests to verify maintenance of operational levels of the equipment in production, and by qualification tests to prove the design capabilities of the equipment to function in the range of environments expected within the spacecraft during a flight. After successfully completing the above tests, the equipment will pass through receiving inspection before going to manufacturing for panel assembly.

18.3.1.2 Panel Assemblies

As circuit design progresses, development tests will be performed to ascertain the fulfillment of requirements and optimum operation. Records of these tests will become a part of the life history of the components. Upon completion of manufacturing assembly, each panel assembly will be acceptance tested to verify that the operational level has been maintained. Specimens will be chosen to be used for qualification testing, the quantity of the specimens being based upon the criticality of the particular panel assembly, as determined by the Reliability group. These tests are to verify that the equipment as designed will fulfill the operational requirements in the environmental conditions of the spacecraft. Further tests will determine the design limit or failure level as a guide to design safety margin.

18.3.1.3 Console

The complete main display console, consisting of the panel assemblies mounted upon the substructure, will be subjected to a limited series of temperature, vibration, and shock tests to prove the design crew safety levels of the substructure and panels. The complete console must survive these tests with no mechanical disintegration.

18.3.2 Interface Area Tests

All panel assemblies with the exception of the entry monitor display and barometric indicator are display and control extensions of their parent system. As such, combined system tests and integrated system tests of the panels become a functional part of the tests of the parent system and will necessarily be integrated with those tests by the responsible system group. System compatibility, calibration, and procedures will be entirely dependent upon the parent system group. Displays and Controls, under these ground rules, becomes the supporting group responsible for maintaining the display and control panels through the various spacecraft checkout operations, with modification drawings, modified panels, and configurations of the console.

The entry monitor display is a completely independent system with its own sensing elements. After installation checkout, all testing will be accomplished by the system self-check capability. The times of these tests will be written into the countdown and flight procedures to cover necessary tests.

18.3.3 Caution and Warning

This system being a malfunction indicator for numerous systems is in the general category discussed in 18.3. The system has a further built-in self-check capability to exercise its own circuits to demonstrate their integrity. The use of this self-test capability will be written into the proper test procedures.

19.0 SIMULATION TEST PLAN*

19.1 SCOPE

Simulation testing provides an engineering and evaluation tool which supports the engineering development program in several ways. Its prime objective is to duplicate anticipated spacecraft performance to the greatest practical extent, in order to demonstrate the adequacy of the integrated system design in fulfillment of the mission.

During an engineering development program, the normal design progression is supported in parallel by simulation testing. This simulation necessarily increases in complexity as the engineering development program progresses. Thus simulation testing is a continuing effort which may be divided into three phases.

During the first phase, preliminary and conceptual design operations are performed utilizing computational equipment. The second phase is concerned with evaluation of the several systems affecting the vehicle dynamics, utilizing both computational equipment and the evaluator complexes. The third phase of the simulation test plan consists of a series of studies conducted for the purpose of system design verification, utilizing prototype hardware, computational equipment, engine simulators and a flight table.

The data obtained from the simulation test plan provides design specifications for the systems and subsystems, and determines system compatibility in the integrated configuration including evaluation of the performance of the man-machine combination. Both preflight and post flight evaluation and verification and duplication of dynamic operations for the various missions are performed as required to support flight test operations.

19.2 OBJECTIVES

19.2.1 Preliminary and Conceptual Evaluation (Phase I)

1. Determine design concepts for systems and subsystems

2. Determine specifications and transfer functions for various systems and subsystems

*Entire section reissued.

3. Determine engineering feasibility of operational procedures

19.2.2 System Evaluation (Phase II)

1. Evaluate design specifications for the various systems

2. Evaluate effect of system gains dead-bands, hysteresis loops, limits, and tolerances on system performance

3. Evaluate interface requirements for guidance and navigation system

4. Evaluate procedures and engineering trade-off techniques to be utilized in the event of system malfunction

5. Evaluate man-in-the-loop performance

6. Evaluate accuracy of the various systems and subsystems

7. Evaluate relative capabilities of various manual and automatic backup modes

8. Evaluate abort procedures for determination of operational requirements

9. Evaluate controls and displays

19.2.3 System Verification (Phase III)

1. Verify dynamic compatibility and performance of integrated systems

2. Verify system specifications

3. Verify mission profiles for the several unmanned and manned tests

4. Verify and evaluate flight test results

5. Verify operational procedures

19.3 REQUIREMENTS

To accomplish the foregoing objectives, certain equipment is necessary. The required equipment includes, but is not limited to the following:

1. Computational equipment, including general purpose analog and digital computers, special logic consoles, and certain specialized interface gear

2. Three evaluator complexes

3. Two simulator complexes

4. Various prototype systems, including the stabilization and control system, the guidance and navigation system, the entry survival system, the reaction control system, and certain communication equipment

5. External visual display equipment including simulated sextant and telescope to provide appropriate visual cues

6. Appropriate equipment for obtaining, processing, and storing required data

7. Special simulation devices such as the service module engine simulator and flight table.

19.4 S&ID TEST PLAN

The schedule for various phases of the simulation test plan is shown in Figure 19-1.

Phase I of the simulation test is presently in progress and has been in operation since early 1962. Phase II of the program was initiated in July 1963 and present plans are for the continuation of this phase through 1965. The final phase of the study will be initiated in the fall of 1964, and will continue to support the program effort.

In the initial phase of the simulation test plan, either analog and/or hybrid computers, or combined computers and simplified desk-top control panels are utilized, depending upon the scope of the simulation study.

The evaluator complexes, which are required for the second phase of the program, are mockups of the command module, with simulated controls, panels, and visual cues.

The simulator complexes, required for the third phase, are copies of boilerplate 14. Continuous updating of the controls and displays and of the simulated systems will be conducted during the final phase of the program. Provisions are made for integrating prototype hardware in the simulator [redacted]. In cases where prototype hardware is not available, bread-boarded systems will be utilized if possible.

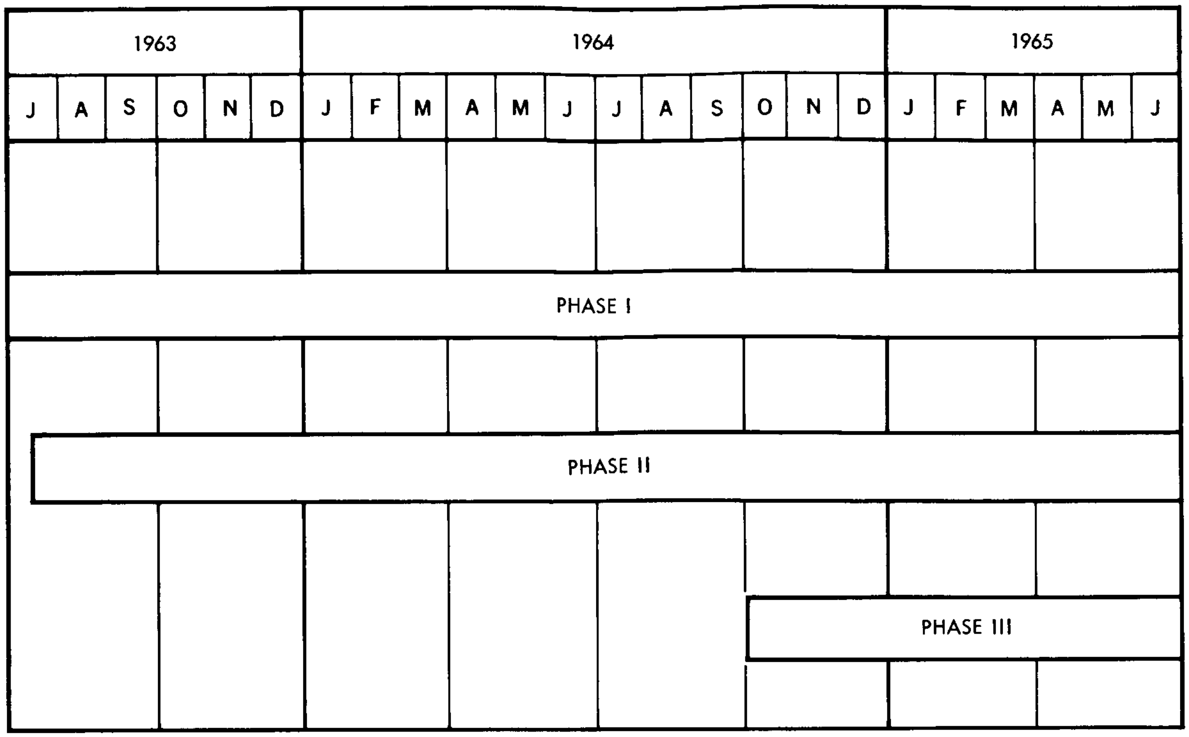

Figure 19-1. Simulation Schedule

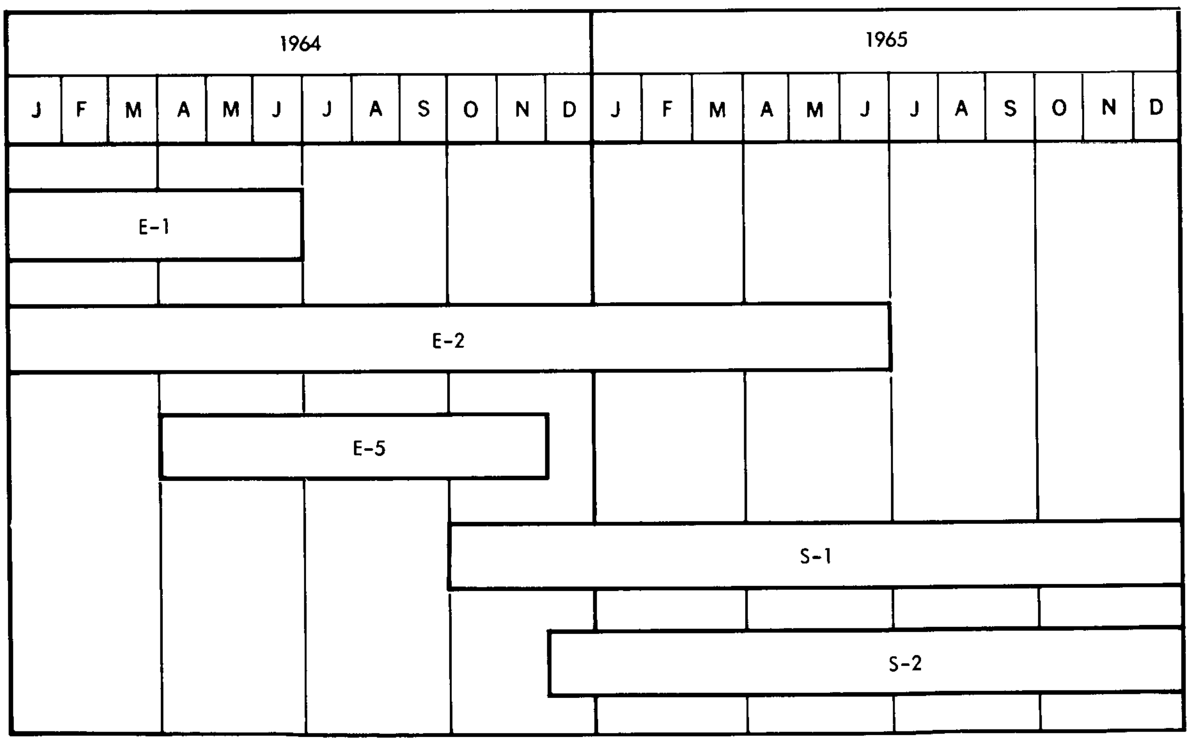

Figure 19-2. Simulator/Evaluator Schedule

[redacted]

Provisions for monitoring the controls and displays during the conduct of any test is provided through the use of closed circuit television and display panels. It is proposed to provide a data acquisition system for both on-line and off-line processing and storing of data. Control and direction of the test is provided by a test conductor utilizing a central control console which is integral to each simulator/evaluator complex.

19.5 FACILITIES

The simulator/evaluator complexes are located in building 4 of the Downey facility, S&ID. The computational devices, both analog and digital, are located in a central area in close proximity to the simulator/evaluator area. Other required special devices will be provided in the immediate area, including data acquisition equipment, visual cues, and special test equipment.

19.6 TEST SCHEDULE

Figure 19-2 presents the latest simulation test schedule for the simulator/evaluator complexes.

19.7 REFERENCES

For detailed information pertaining to this section refer to SID 63-1040, Apollo Simulation Program Plan.

[redacted]

20.0 ENTRY MONITOR SYSTEM

20.1 SCOPE

The test program will include design verification, evaluation, qualification, off-limit/marginal, and acceptance testing. These tests will be conducted by Autonetics under the direction of S&ID specifically to provide maximum confidence in the design and operational integrity of the EMS and its anticipated reliability.

20.2 SUBCONTRACTOR TEST PLAN

Not applicable.

20.3 S&ID TEST PLAN

20.3.1 Objectives

The primary objective is to assure that all requirements of the EMS procurement specification are met and that the EMS is capable of performing its required mission with optimum reliability. The EMS test program starts with a series of system level qualification tests. These tests will confirm proper design and operational characteristics. The program then progresses to the static vehicles for installation compatibility under environmental exposure. The final step in obtaining full flight qualification is the exposure to actual flight environment on unmanned recoverable vehicles.

20.3.2 Test Plan

S&ID will be responsible for accomplishing a complete program of engineering design, development, and qualification tests. The details of this effort will be derived as the detailed design of the EMS becomes firm, but in all cases it will assure complete testing of both purchased and manufactured parts and components. The scope of testing will include, but will not be limited to, exposure to environmental conditions as specified for command module electrical systems.

System level testing will subject the EMS to applicable Apollo environmental exposures and will evaluate the over-all design for conformance to specification, operational integrity, and reliability.

The results of these design verification tests will be used to confirm the mathematical model and to initiate redesign if needed.

The EMS contains a self-check feature which is adequate for all testing after installation in the CM. This test will be used as required during integrated and combined systems tests to assure proper EMS operation in conjunction with all other systems used during entry. Also it will be used to check the interfaces with the primary power system and the caution and warning (C&W) subsystem.

Flight qualification of the EMS will include subjecting it to the environmental exposures scheduled for AFRM 006 and 008, and by subjecting it to the actual flight environment as experienced on the first recoverable flights of each booster configuration, AFRM 009, 020, and 029.

Three prototype and one dummy EMS will be built and used to conduct a complete design proof and qualification test series. Partially qualified systems will be used as required to support early integration efforts in the various spacecraft. This equipment will be upgraded or replaced with fully-qualified hardware prior to subjection to environmental or flight testing.

20.3.2.1 Qualification Tests

These tests will be conducted to determine that the EMS functions within specified tolerances when subjected to the expected Apollo environment. The tests will include, but will not necessarily be limited to:

- Shock
- Oxidation-explosion
- Temperature
- Vibration
- Acoustics
- Humidity and salt fog
- Vacuum
- Sustained acceleration
- Variations of primary power
- EMI
- Various combinations of the above

These tests, or appropriate portions thereof, will be repeated as required each time that a significant change is made in EMS design, fabrication processes, etc.

20.3.2.2 Design Proof Off-Limit/Marginal Testing

Tests will be conducted on the EMS which will exceed the design limits in order to determine actual operational ranges of the system. During these tests, data will be collected to determine whether design changes are required.

20.3.2.3 Acceptance

The EMS will be subjected to an acceptance test prior to delivery for spacecraft installation. The test will verify that the EMS is functioning as required by the procurement specification.

20.3.2.4 Integrated Systems Tests

These tests will verify the physical and electrical compatibility of the EMS with the spacecraft and all other systems and will confirm this compatibility under expected flight environment conditions.

20.3.2.4.1 Interfaces.

20.3.2.4.1.1 Physical Compatibility. An engineering model (or qualified model) will be installed in each house spacecraft to assure that there are no interference problems with primary or mounting structure. These installations also will determine the compatibility of installation and alinement procedures.

20.3.2.4.1.2 Electrical Compatibility. The house spacecraft installations will be used to prove the compatibility of the EMS with other spacecraft systems when operating from the common primary power source. Tests will include verification of the spacecraft's redundant power circuits and protective devices.

20.3.2.4.2 EMI. Subsequent to installation in each spacecraft, the EMS will be tested as an integral part of the total spacecraft systems for compliance with all applicable Apollo specifications governing susceptibility to, and radiation of, electromagnetic and radio frequency interference.

20.3.2.4.3 Environmental Airframes.

20.3.2.4.3.1 Airframe 006. A qualified EMS will be installed in AFRM 006 for systems compatibility tests during spacecraft exposure to anticipated flight vibration and acoustical environment.

20.3.2.4.3.2 Airframe 008. A qualified EMS also will be installed in AFRM 008 for systems compatibility tests during spacecraft exposure to anticipated flight combinations of vibration, temperature, and vacuum environments.

20.3.2.5 Flight Qualification

20.3.2.5.1 Unmanned Vehicles. EMI will be tested on most of the unmanned recoverable flights to demonstrate their complete qualification in actual flight environment prior to committing them to manned flight. The tests will be divided into three general phases: (1) entry from circular orbit, (2) supercircular orbit entry (26 to 30K fps), and (3) lunar return type entry (36K fps). Instrumentation of critical parameters will be used to allow post-flight analysis of system performance.

20.3.2.5.2 Manned Vehicles. Final qualification requires a man-in-the-loop operation. First manned flights will use the EMS to monitor entry from circular orbit with manually-controlled entry being used on a latter flight. The same sequence will be used to verify both monitored and manually-controlled entry at supercircular and lunar return velocities prior to the first lunar mission.

20.3.3 Equipment

20.3.3.1 Simulator, Evaluator, Trainer Hardware

Partial or simulated EMS will be provided for the various simulator, evaluator, and trainer programs. These systems will contain essentially duplicates of the display portion of the EMS if feasible. Modification of the method of energizing the various display elements will be incorporated, as required, to make the units compatible with their intended usage. No inertial sensors, comparators, etc., will be included in these systems. They will be passive devices which operate in response to drive signals from external computers.

The operational and display method of the EMS will be checked for the astronauts' reactions to its functional compatibility from the human engineering viewpoint.

20.3.4 Facilities

20.3.4.1 GSE and BME

An important design aim of the EMS is to include a comprehensive and high confidence self-test routine. Failure to pass the self-test would dictate replacement of the EMS with a spare. This test philosophy, which requires no GSE or BME, was chosen as the most compatible, economical, and efficient approach.

All testing listed in this test plan except Paragraph 0.3.2.4.3 Environmental Airframes*, and Paragraph 0.3.2.5 Flight Qualification*, will be conducted at the Autonetics, La Palma facility. Autonetics in-plant environmental test equipment that is capable of performing all of the required tests will be used. Details on the environmental test equipment will be included when available.

20.3.5 Test Schedules

The entry monitor test schedule is shown in Figure 20-1.

*General Test Plan (SID 62-109-5) Volume V

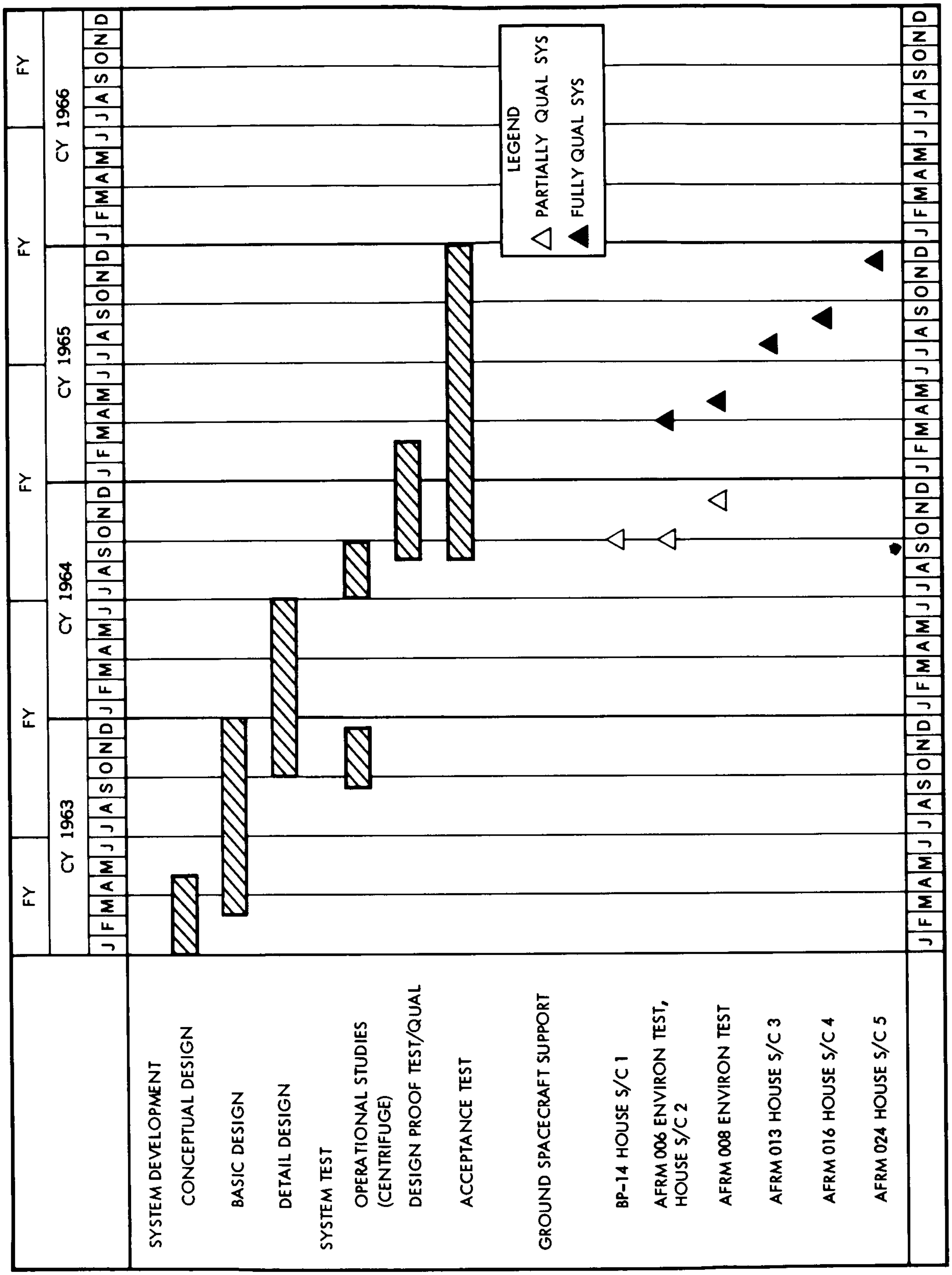

Figure 20-1. Entry Monitor System Test Schedule

21.0 NUCLEAR RADIATION PROTECTION

21.1 SCOPE

This section describes the planned approach to the determination of system degradation in a nuclear space radiation environment. Although a particular system may not contain components or materials that will suffer permanent radiation damage, there is a probability that transient effects may occur in a nuclear radiation field. These effects may cause changes in system parameters that would make the system useless or would degrade its performance enough to adversely affect mission success.

21.2 S&ID TEST PLAN

21.2.1 Objectives

Certain systems employed in the Apollo spacecraft may be adversely affected by nuclear space radiation. This test plan ascertains the effect of the radiation field on system operation and relates these effects to mission success. Permanent radiation damage investigation is not part of the test objectives. The test objectives include:

1. Determine the radiation environment of the component
2. Determine the system parameters on which radiation has an effect
3. Analyze system for type and amount of degradation by radiation environment
4. Subject systems that analysis reveals are sensitive to irradiation to a simulated radiation environment
5. Maintain irradiation levels during test as the particular missions where the system is used
6. Recommend corrective procedures to eliminate or reduce problems to a level of noninterference with the mission success, based on test results.

21.2.2 Test Plan

The test plan consists of the following items:

1. Long range tests involve systems such as the environmental control system, the high gain antenna, the Apollo propellant gaging system, television camera, and data communication subsystem.

2. Exposures to simulated space nuclear radiation will be made for typical Apollo missions. The range of fluxes and flux rates for electrons, protons and alphas will bracket the various expected mission profiles, and an attempt will be made to establish system degradation as a function of total flux and flux rates.

3. The environments chosen will be similar to the space environments.

4. Each system will be analyzed for its effect on overall mission performance.

5. Analysis of test results will be extrapolated to space environment.

21.2.3 Equipment Required

The equipment required includes the following:

1. Space nuclear radiation test equipment package with subcomponents including detectors, amplifiers, power supplies, and multichannel analyzer

2. Vacuum chambers and fixtures for irradiation tests

3. Beam time on accelerators (purchased as the need arises)

21.2.4 Facilities

No new facilities are needed, as existing NAA facilities are adequate for preliminary checkout of the test setup. Accelerator sites are sufficient for carrying out the necessary experimental work.

21.2.5 Test Schedules

Tests will be carried out as the need arises. Since the tests are not independent of system finalization, it is anticipated that the testing program will continue through February 1966 (end of programmed engineering effort).

[redacted] [redacted]

NOMENCLATURE

A listing of the special nomenclature and abbreviations used in this report is presented. These listings may appear interchangeably with their full definitions in the text. Accepted abbreviations for units of physical measurement such as volts, ohms, etc. are not included.

Abbreviation	Definition
AEDC	Arnold Engineering Development Center
AFMTC	Air Force Missile Test Center
AFRM	Airframe
AGAP	Attitude gyro and accelerometer package
AGC	Aerojet-General Corporation
AGC	Automatic Gain Control
AGC	Apollo guidance computer
AGREE	Advisory group on reliability of electronic equipment
AMR	Atlantic Missile Range
ATO	Apollo Test and Operations
BAL	Balance
BCD	Binary coded decimal
B-#	Boilerplate - # (with specific number)
B/M	Bench maintenance
BOD	Beneficial Occupancy Date
BMAG	Body-mounted attitude gyros

[redacted]

Abbreviation	Definition
B/P	Boilerplate
CCMTA	Cape Canaveral Missile Text Annex
C&D	Controls and displays
CDS	Communications and data subsystems
CDU	Coupling display unit
CG	Center of gravity
C&IS	Communications and instrumentation system
C/M	Command module
C/O	Checkout
C-O	Crew operated
CP	Control panel
CTU	Central timing unit
CVR	Change verification record
DEA	Display electronic assemblies
DF	Direction finding
DOD	Department of Defense
DOF	Degrees of freedom
DP	Design proof
DPT	Design proof test
DSIF	Deep Space Instrumentation Facility

Abbreviation	Definition
DVD	Differential velocity display
EBW	Exploding bridge wire
ECA	Electronic control assembly
ECS	Environmental control system
EDL	Engineering Development Laboratory (S&ID Dny)
ELS	Earth landing system
EMI	Electromagnetic interference
EPS	Electrical power system
ET	Escape tower
FDAI	Flight director attitude indicator
FM	Frequency modulation
FAX	Facsimile transmission
G, g	Acceleration of gravity
G&NS	Guidance and navigation system
GOSS	Ground operational support system
GP	General purpose
GPI	Gimbal position indicator
GSE	Ground support equipment
HAA	High-altitude abort
HBW	Hot bridge wire
H/A	Hazardous area

Abbreviation	Definition
IFT&M	In-flight test and maintenance
IMCC	Integrated Mission Control Center
IMU	Inertial measurements unit
INT	Interior
INST REF	Instrument reference
IRIG	Inter-range instrumentation group
L-	Time before launch (days)
LAD	Los Angeles Division (or NAA)
L/D	Length-diameter ratio
LEM	Lunar excursion module
LEV	Launch escape vehicle
LES	Launch escape system
LJII	Little Joe II
LOR	Lunar orbit rendezvous
LSS	Life support system
L/V	Launch vehicle
MDSS	Mission data support system
M-#	Mock-up - # (with specific number)
Max q	Maximum dynamic pressure
MEE	Mission essential equipment

[redacted] [redacted]

Abbreviation	Definition
MIT	Massachusetts Institute of Technology
MLT	Mission life test
MNEE	Mission non-essential equipment
MSC	Manned Spacecraft Center (NASA, Houston, Texas)
MTBF	Mean time before failure
MTTR	Mean time to repair
NAA	North American Aviation
NASA	National Aeronautics and Space Administration
O/F	Oxidizer-to-fuel ratio
OPS	Operations
OTP	Operational test procedure
PA	Power amplifier
PACE-S/C	Prelaunch automatic checkout equipment - spacecraft
PAM	Pulse amplitude modulation
PCM	Pulse coded modulation
P_c	Pressure chamber
PDM	Pulse duration modulation
P_f	Probability of failure
P_{f_p}	Probability of performance failure
P_{f_s}	Probability of stress failure
PFRT	Preliminary flight rating test
POD	Prelaunch Operations Division (NASA)

[redacted]

Abbreviation	Definition
P_s	Probability of success
PSA	Power and servo assembly
PTT	Push to talk
PUCS	Propellant utilization control system
P&WA	Pratt & Whitney Aircraft
R/B	Radar beacon
R/C	Radio command
RCC	Range control center
RCS	Reaction control system
R&D	Research and development
REG	Regulator
RF	Radio frequency
RFI	Radio frequency interference
RFWAR	Requirements for work and resources
RGP	Rate gyro package
R&Z	Range and zero
SA	Saturn Apollo
SCAT	Space communications and tracking
SCD	Specification control drawing
SCIP	Self-contained instrumentation package
SCO	Subcarrier oscillator
SCR	Silicon-controlled rectifier

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Abbreviation	Definition
SCT	Scanning telescope
S/C	Spacecraft
S/C_a	Spacecraft adapter
SCS	Stabilization and control system
SEP	Space electronic package
S&ID	Space and Information Systems Division (of NAA)
S/M	Service module
SOL	Solenoid
SOFAR	Sound fixing and ranging
SPS	Service propulsion system
STU	Systems test unit
SXT	Sextant
T-	Time before launch
T-O	Time of launch
T+	Time after launch
T/M	Telemeter
TP	Test point
TPA	Test preparation area
TPS	Thermal protection system
T/R	Transmitter receiver (combination in two packages)
TWT	Traveling wave tube
TWX	Teletype wire transmission

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Abbreviation	Definition
UDMH	Unsymmetrical dimethyl hydrazine
VCO	Voltage controlled oscillator
VLF	Vertical launch facility
VSWR	Voltage standing wave ratio
WSMR	White Sands Missile Range
XCVR	Transceiver (transmitter receiver in one package)

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DEFINITION OF TERMS*

ABLATE — To carry away; to remove by cutting or erosion, melting or evaporation. To undergo ablation; to become melted or vaporized and removed at a very high temperature.

ABORT — An uncompleted missile flight or an uncompleted hold-down test resulting from a failure of equipment or of a system other than the one undergoing test. In a tactical operation (simulated or real) a missile failure either on the ground or in flight; a missile that fails to complete a programmed flight.

ADAPTER — Flange or extension of a vehicle stage or section providing a means of fitting another stage or section to it.

AEROBALLISTICS — Term derived from aerodynamics and ballistics, dealing primarily with the motion of bodies whose flight path is determined by applying the principle of both sciences to different portions of the path.

AEROTHERMODYNAMIC BORDER — Area above an altitude of about 100 miles where the atmosphere becomes so rarefied that there is no longer any significant heat-generating air friction on the skin of vehicles.

AIRFRAME — Assembled structural and aerodynamic components of an aircraft or missile.

ALBEDO — The ratio of light reflecting from an unpolished surface to the light falling upon it. Term is used in reference to light reflected from the moon or planets.

AMBIENT CONDITIONS — Environmental conditions such as pressure or temperature; naturally existing conditions.

ANTHROPOMORPHIC — Human-like; related to or designed for the human body.

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APOLLO	NASA designation for follow-up manned space-flight program to Project Mercury manned orbital mission. Apollo spacecraft is to be suitable for manned earth-orbiting laboratory, manned circumlunar flight, manned lunar landing, and return.
ATLANTIC MISSILE RANGE (AMR)	A 5000- to 6000-mile instrumented range for testing ballistic and guided missiles located between Cape Kennedy, Florida, and a point beyond Ascension Auxiliary AFB, near the middle of the South Atlantic.
ATTITUDE	Orientation of an air vehicle as determined by the inclination of its axis to a frame of reference, usually the earth.
ATTITUDE JETS	Sometimes called steering jets, attitude-control jets or roll, pitch, and yaw jets; fixed or movable gas nozzles on a rocket, missile, or satellite operated continuously or intermittently to change attitude or position.
AXIS, AXES	Reference axes in the Apollo spacecraft are as follows:
X-axis	The X-axis is parallel to the nominal launch axis and is positive in the direction of initial flight.
Y-axis	The Y-axis is normal to the X-axis and is positive to the right of a crewman when the crewman is in his seat facing toward positive "X."
Z-axis	The Z-axis is normal to both the X- and Y-axes and is positive in the direction of the crewman's feet when he is in his seat.
BACKUP	Designed to immediately follow an earlier space system or a project to complement the latter or take advantage of new techniques and processes; a system that can replace a failed system.

BENCH MAINTENANCE EQUIPMENT	Equipment supporting component and subsystem testing; facilities capable of isolating, defining, and providing remedial action to malfunctions.
BIOMEDICINE	Combined discipline of biology and medicine for analysis of human tolerances to and protection against environmental variances.
BOILERPLATE	Simulated module for predevelopmental and developmental tests leading to the design of the spacecraft module.
BOOSTER ENGINE	An engine, especially a booster rocket, that adds thrust to the thrust of the sustainer engine, or provides propulsion for a special phase of flight.
BREADBOARD MODEL	An assembly of preliminary circuits and parts to prove the feasibility of a device, circuits, equipment, system or principle in rough or breadboard form without regard to the eventual over-all design or form of parts.
BRIDGE WIRE	The ignition resistor filament. The bridge wire heats the primary explosive to initiate the explosion.
CELESTIAL GUIDANCE	The act of determining and/or positioning a moving body between two points with respect to the celestial bodies.
CENTRIFUGE	A large motor-driven apparatus with a long rotating arm at the end of which human and animal subjects or equipment can be revolved at various speeds to simulate accelerations encountered in high-performance vehicles.
CHECKOUT	A sequence of operational and calibrational tests needed to determine the condition and status of a required operation or function.

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COASTING FLIGHT	The flight of a rocket or other vehicle between burnout or thrust cutoff of one stage and ignition of another, or between final burnout and summit altitude or maximum range. Also the unpowered portion of an interplanetary flight.
COMMAND MODULE	Personnel and control vehicle in the Apollo spacecraft configuration containing command and communication facilities and crew provisions.
COMPATIBILITY	The quality that permits an item to function in harmony with other equipment and fulfill all design objectives.
CONFIGURATION	The physical nature of an item; the physical arrangement of components which comprise a spacecraft and its dimensions.
CONSOLE	Master instrument panel from which rocket and missile launchings and test are controlled; a group of controls, indicators, and similar electrical or mechanical equipment that is used to monitor readiness of and/or control specific functions such as missile checkout, countdown and launch operations.
COUNTDOWN	Series of numbered events and checks that take place from the start of rocket-launching operations until the rocket lifts off the launch stand.
CRYOGENIC FUEL	A rocket fuel that either in itself is kept at very low temperatures or combines with an oxidizer kept at very low temperatures.
CUTOFF	The shutting off of a liquid or solid-propellant combustion process of a rocket engine, causing a rapid drop toward zero thrust (intentional command action).
DEEP SPACE INSTRUMENTATION FACILITY (DSIF)	Communication equipment capable of contacting and tracking spacecraft beyond normal ranges. DSIF facilities are located at Woomera, Australia; Johannesburg, South Africa; and Goldstone, California.

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DEMONSTRATE — Denotes the occurrence of an action or an event during a test. The accomplishment of this type of objective requires a qualitative answer. The answer will be derived through the relation of this action or event to some other known information or occurrence. This category of objectives implies a minimum of system instrumentation and/or that information be obtained external to the test vehicle.

DESIGN VERIFICATION TEST — Basic development test used to determine the adequacy of the design over the anticipated operating conditions. A design verification test is always conducted by Engineering and on a breadboard level.

DETERMINE — Denotes the measuring of performance of any unit or system. This category implies the quantitative investigation of over-all operation, which includes, generally, instrumentation for measuring basic inputs and outputs of the unit or system. The information obtained should indicate to what extent the system is operating as designed. The instrumentation should allow performance deficiencies to be isolated to either the system or the system inputs.

DRAG — The resistance of a body to motion in a medium such as air.

DRY WEIGHT — Weight of a rocket vehicle without its fuel and usually without payload.

EARTH LANDING SUBSYSTEM (ELS) — Acceleration-decreasing equipment for return to the earth's surface after atmospheric reentry; may consist of a parachute system, a flexible aerodynamic glider configuration, or both.

ENGINEERING DEVELOPMENT PART — A part or unit to be employed in a breadboard design.

ENVIRONMENTAL CONTROL SUBSYSTEM (ECS) — The components controlling crew conditions in the spacecraft; governing factors of atmosphere, pressure, and temperature; and providing support for spacesuit conditions in event of cabin decompression or extra vehicular operations.

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EVALUATE
Denotes the measuring of performance of any unit or system, as well as the performance and/or interaction of its sections or subsystems that are under investigation. The accomplishment of objectives of this type requires quantitative data on the performance of both the unit or system, and its sections or subsystems will be analyzed for their contribution toward performance of the unit or system. This category will provide the most detailed information of any of these categories.

FALLAWAY SECTION
Any section of a rocket vehicle that is cast off and falls away from the vehicle during flight, especially such a section that falls back to earth.

FIRST MOTION
First indication of motion of the missile or test vehicle from its launcher. Synonymous with "takeoff" for vertically launched missiles.

FLIGHT READINESS FIRINGS (FRF)
A missile system test consisting of the complete firing of the liquid-propellant engines of a rocket missile while it is restrained in its launching stand to verify the readiness of the missile for a flight test or mission.

FREE-FLIGHT TRAJECTORY (Free Fall Ellipse)
That part of a ballistic missile's trajectory that begins with thrust cutoff and ends at reentry.

FUEL CELL
A source of electrical power analogous to a common electrical cell with the reactants continually replenished from an external supply.

GAMMA RADIATION
Electromagnetic radiation having a high degree of penetration similar to X-rays originating from the nucleus.

GEMINI
NASA follow-up program to Mercury; a two-man spacecraft to demonstrate rendezvous and docking techniques, longer orbital flights (to 14 days), controlled reentry, and landing.

GIMBALED MOTOR
A rocket motor mounted on a gimbal, i. e., on a contrivance having two mutually perpendicular axes of rotation so as to correct pitching and yawing.

GODDARD SPACE FLIGHT CENTER (GSFC)
NASA research center at Greenbelt, Maryland, named for Robert H. Goddard, American rocket pioneer.

GOLDSTONE TRACKING FACILITY
A deep space instrumentation facility located at Army's Camp Irvin, Barstow, California, using a radiotelescope and operated for NASA by Jet Propulsion Laboratory (JPL).

GO NO-GO
A missile launch controlled at the end of the countdown as to permit an instantaneous change in decision on whether or not to launch.

GROUND OPERATIONAL SUPPORT SYSTEM (GOSS)
Network of tracking stations, fixed and mobile, air, ground, and seaborne to communicate with, track, and telemeter spacecraft and satellites.

GROUND SUPPORT EQUIPMENT (GSE)
All ground equipment that is part of the complete spacecraft system and that must be furnished to ensure its support. All implements or devices required to maintain the functional operational status of the spacecraft are included. In the Apollo program, bench maintenance equipment, combined system test unit, and prelaunch automatic checkout equipment comprise the GSE.

GUIDANCE
(1) The process of intelligence gathering and maneuvering required by a missile, probe, or space ship to reach a specified destination. (2) General term includes entire scheme: sensing devices, computers, and servo systems.

HEAT SHIELD	An ablative protective covering to ensure spacecraft and crew survival through the hypertemperatures of atmospheric reentry.
HEAT SINK	A device that absorbs heat energy.
HOT TEST	Propulsion system test conducted by actually firing the propellants. A hot test may be live, static, or conducted in a confined place.
INERTIAL GUIDANCE	An onboard guidance system for space and satellite vehicles where gyros, accelerometers, and possibly a gyro-stabilized platform satisfy guidance requirements without use of any ground-located components.
INFRARED LIGHT	Light in which the rays lie just beyond the red end of the visible spectrum.
INITIATOR	A primary explosive mixture used as a primer, detonator for caps which initiates the explosion of blasting propellant, bursting explosives at the desired moment.
INTERIM QUALIFIED	A term used to describe the status of a component or system scheduled for use in early flights wherein the basically essential qualification tests have been successfully completed as related to the specific flight objectives.
INVERTER	A converter to a-c power from a d-c source.
JET STEERING	The use of fixed or movable gas jets on a space vehicle, ballistic missile, or sounding rocket for thrust vector control to steer it along a desired trajectory, during both propelled flight and after thrust cutoff.
KELVIN SCALE (K)	A scale of temperature measured in degrees Centigrade from absolute zero, -273.18 C.

LANGLEY RESEARCH CENTER
NASA installation in Hampton, Virginia, responsible for technical research in development and improvement in both atmospheric and space flight.

LAUNCH WINDOW
The allowable limits of launch time that will allow a spacecraft to achieve successful injection into programmed flight path.

LAUNCH ESCAPE SUBSYSTEM (LES)
The components for command module recovery in case of mission abort after launch and prior to orbit. The system consists of the launch escape motor, the launch escape tower, and the tower jettison motor.

LIQUID HYDROGEN
Supercooled and pressurized hydrogen gas used as a fuel. As rocket fuel, it develops a specific impulse, when oxidized by liquid oxygen, ranging between 317 and 364 seconds depending upon the mixture ratio.

LIQUID OXYGEN
Oxygen supercooled and kept under pressure so that its physical state is liquid. Used as an oxidizer.

LITTLE JOE (I, II)
A solid-rocket test vehicle developed by General Dynamics. I was used to test the Mercury capsule, and II will be used to test the Apollo spacecraft.

LUNAR EXCURSION MODULE
The two-man vehicle that will land on the moon after the Apollo spacecraft enters lunar orbit.

LUNAR ORBITAL RENDEZVOUS
The concept for manned lunar landing adopted by NASA wherein the lunar excursion module leaves the spacecraft, lands on the moon, and later returns to the orbiting spacecraft. The excursion module will be jettisoned as the spacecraft leaves lunar orbit.

MANNED SPACECRAFT CENTER (MSC)
NASA headquarters responsible for development and operation of manned space vehicles (Mercury, Gemini, Apollo), located in Houston, Texas.

MARSHALL SPACE FLIGHT CENTER (MSFC)	NASA operation responsible for design and development of space launch vehicles (Saturn, Advanced Saturn, Nova), located in Huntsville, Alabama.
MOCK-UP	A full-scale, three-dimensional representation of a complete spacecraft, individual module, and/or related equipment.
MODULE	A combination of components, contained in one package or so arranged that together they are common to one mounting, which provides a complete function. (See command module, service module, lunar excursion module, etc.)
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)	Civilian agency, sponsored by the U. S. Government, with research and development jurisdiction in aeronautical and space activities except those activities peculiar to or primarily associated with the development of weapon systems, military operations, or the defense of the United States.
NAUTICAL MILE (NM)	A measure of distance equal to 6,076.103 feet or approximately 1.15 mile.
OBTAIN DATA	Denotes gathering engineering information that is to be measured to augment the general knowledge required in the development of the over-all spacecraft. This category may also be used for supplemental investigation, such as environmental studies, ground equipment studies, etc. The degree of instrumentation is not implied by this definition.
OPTICAL STAR TRACKER	A star tracker that locks onto the light of a particular celestial body. Distinguished from a radiometric star tracker. (See star tracker.)
OXIDIZER	A rocket propellant component, such as liquid oxygen, nitric acid, fluorine, and others, that supports the combustion of a fuel.

PAD	A permanent or semipermanent load-bearing surface constructed or designed as a base upon which a launcher can be placed. Short for launch pad.
PITCH	The movement about an axis that is at once perpendicular to the Apollo longitudinal axis and parallel to the Y-axis of the spacecraft.
PRE-QUALIFIED	A pre-qualified part or component is one that has been scheduled as the one most likely to succeed in the qualification program and will be used in production runs as well as during developmental test or early flight test prior to qualification.
PRESSURIZED SUIT	A garment designed to provide pressure upon the body so that respiratory and circulatory functions may continue normally, or nearly so, under low-pressure conditions, such as occur at high altitudes or in space without benefit of a pressurized cabin.
PROGRAMMED ROLL	An automatically controlled roll of a ballistic missile or satellite, usually executed during its vertical ascent before pitch-over.
PROGRAMMED TURN	The turn of a ballistic missile from vertical motion, after lift-off, to a curved path approximating the desired powered flight trajectory prior to the initiation of guidance.
PROPELLANT	A liquid or solid substance burned in a rocket for the purpose of developing thrust.
PROTOTYPE	A model suitable for evaluation of mechanical and electrical form, design, and performance. It is in final mechanical and electrical form, employing approved parts, and representative of the final equipment.
QUALIFICATION OF PART, COMPONENT, OR SYSTEM	A part, component, or system is considered qualified after it has successfully completed all of the prescribed tests associated with relevant control specifications.

READOUT	A visual display of data.
RECOVERY	The act of retrieving a portion of a launched missile or satellite.
REENTRY	Return of a part of a space vehicle to the atmosphere after flight above the sensible atmosphere.
RELIABILITY	Reliability is the probability of performing without failure a specified function, under given conditions, for a specified period of time. It deals with the failure rates in time of specified items.
RETROROCKET	Relatively small rocket unit, usually solid propellant, installed on a rocket-propelled vehicle and fired in a direction opposite to the main motion to decelerate main unit.
ROLL	The movement of Apollo about its longitudinal (X) axis.
SATURN	The sun's sixth planet. A NASA rocket engine cluster in research and development expected to develop some 1,500,000 pounds of first-stage thrust. The Apollo launch vehicle.
SEPARATION	Moment when a full stage, half stage, a warhead, or a nose cone is separated from the remainder of the rocket vehicle; the moment when staging is accomplished.
SERVICE MODULE	Apollo module carrying propulsion equipment, fuel, reaction control systems, and communications power. It is used for thrust after booster separation, mid-course correction, lunar orbit, lunar orbit ejection, and earth return midcourse correction. It is jettisoned prior to reentry.
SERVICE PROPULSION SYSTEM	Engine and associated equipment providing thrust for service module functions. (See SERVICE MODULE.)

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SOFT LANDING — Landing on the moon or other spatial body at such slow speed as to avoid damage of landing vehicle. Soft landings on moon are anticipated by use of retrorockets.

SOLAR FLARE — Solar phenomenon that gives rise to intense ultraviolet and corpuscular emission from the associated region of the sun. This affects the structure of the ionosphere and interferes with communications.

SOLID PROPELLANT — A propellant in solid condition including all the ingredients necessary for sustained chemical combustion, such as a compound of fuel and oxidizer, usually in plastic caked form. It burns on its exposed surface, generating hot exhaust gases to produce a reaction force.

SPACECRAFT — In the Apollo program, any component or combined components of the flight vehicle not part of the launch vehicle: launch escape subsystem, command module, service module, adapter, or any combination of these.

SPECIFIC IMPULSE — The thrust produced by a jet-reaction engine per unit weight of propellant burned per unit time, or per mass of working fluid passing through the engine in unit time. It is equal to thrust in pounds divided by weight flow rate in pounds per second.

STABILIZATION AND CONTROL SUBSYSTEM (SCS) — An Apollo system used to provide orientation, stabilization, and control functions for the CM/SM under the influence of either the G&N or the crew.

STAGE — In a rocket vehicle, powered by successive units, any one of the separate propulsion units is known as a stage.

STAGNATION POINT — The location on a surface in an airstream where the air flow is zero.

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STAR TRACKER	An optical device used for the purpose of determining the relative position of a moving object with respect to celestial bodies.
STATIC TESTING	Testing of a missile or other device in a stationary or holddown position, to verify structural integrity, to determine the effects of limit loads, or to measure thrust.
SYSTEMS PROGRAMMING	Process of organizing and utilizing all technical disciplines necessary for the design and development of complex systems.
TELEMETERING	The technique of recording space data by transmission of instrument readings from a rocket to a recording machine on the ground.
THEODOLITE	An optical device used to determine horizontal or vertical angles.
TRAJECTORY	The path described by a missile or a space vehicle.
TRANSFER ELLIPSE	Path followed by a body moving from one orbit to another.
ULLAGE	The amount of fluid by which a tank falls short of being full.
UMBILICAL	Any one of several electrical or fluid lines connected between the ground support operation and an uprighted rocket missile or space vehicle before launch.
UNSYMMETRICAL DIMETHYLHYDRAZINE (UDMH)	Rocket fuel which is hyperbolic with nitrogen tetroxide. This provides restart capability without an ignition system.
VECTOR STEERING	Vernacular for a steering method where one or more thrust chambers are gimbal mounted so that the direction of the thrust force (thrust vector) may be tilted in relation to the center of gravity of the missile to produce turning.

VELOCITY VECTOR	Combination of two ballistic missile trajectory values: the speed of the missile's center of gravity at a designated point on the trajectory and angle between local vertical and the direction of the speed.
WHITE SANDS MISSILE RANGE (WSMR)	A proving ground in New Mexico under the control of the Army Ordnance Missile Command; supports Apollo abort tests.
YAW	Lateral movement of the Apollo spacecraft along the Z-axis in line of flight.

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